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Reclamation Research

Annual Report - 1989



Heritage Fund

Alberta

LAND CONSERVATION AND
RECLAMATION COUNCIL
Reclamation Research
Technical Advisory Committee

DISCLAIMER

This report is intended to provide government, industry and the public with a summary of the research that is being carried out by the provincial government's Reclamation Research Technical Advisory Committee. Additional information on the Reclamation Research Program and additional copies of this report may be obtained by contacting:

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RECLAMATION RESEARCH

ANNUAL REPORT - 1989

prepared by

The Reclamation Research Technical Advisory Committee

for the

ALBERTA LAND CONSERVATION AND RECLAMATION COUNCIL

1990

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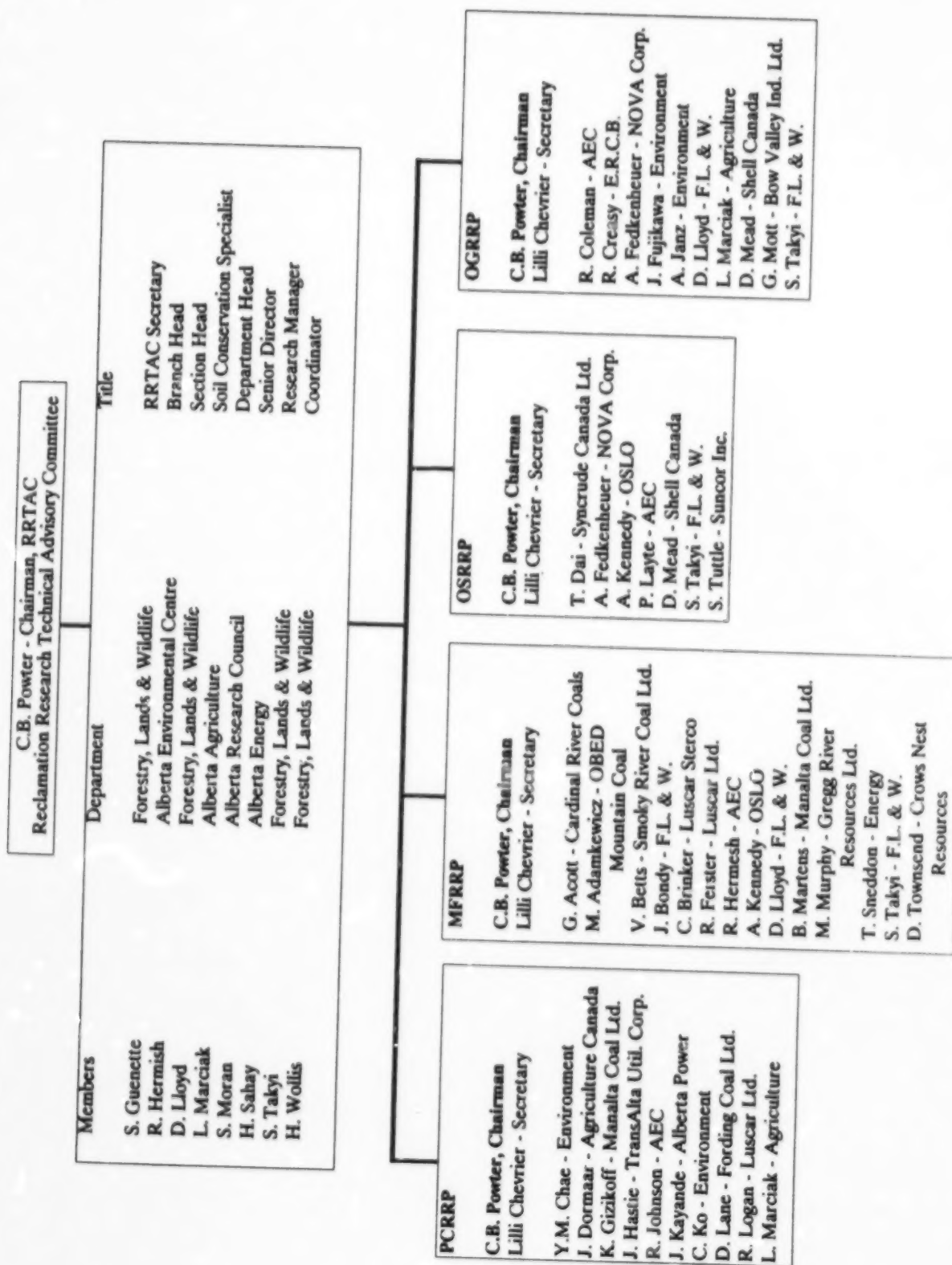
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1. INTRODUCTION

Regulating surface disturbances in Alberta is the responsibility of the Land Conservation and Reclamation Council. The Council executive consists of a chairman from the Department of Environment (Mr. John King, Director, Land Reclamation Division) and two deputy chairmen from the Department of Forestry, Lands and Wildlife (Mr. Roger Marvin, Director, Land Management and Development Branch and Mr. Don Fregren, Director, Forest Land Use Branch). Among other functions, the Council oversees programs for reclamation of abandoned disturbances and reclamation research. The Reclamation Research Program was established in 1978 to identify the most efficient methods for achieving acceptable reclamation in Alberta. Funds for implementing both the operational and research programs are drawn from Alberta's Heritage Savings Trust Fund, Land Reclamation Program.

To assist with the development and administration of the research program, the Council appointed the Reclamation Research Technical Advisory Committee (RRTAC). The Committee consists of six members and a secretary:

Chris Powter (Chairman) - Alberta Environment, Land Reclamation Division

Sharon Guenette (Secretary) - Alberta Forestry, Lands and Wildlife, Forest Land Use Branch

Leon Marciak - Alberta Agriculture, Conservation and Development Branch

Reinhard Hermesh - Alberta Environmental Centre, Plant Sciences Division

David Lloyd - Alberta Forestry, Lands and Wildlife, Public Lands Division

Sam Takyl - Alberta Forestry, Lands and Wildlife, Alberta Forest Service

Stephen Moran - Alberta Research Council, Terrain Sciences Division.

The following are ad-hoc members of RRTAC:

Hugh Wollis - Alberta Forestry, Lands and Wildlife, Fish and Wildlife Division

Hari Sahay - Alberta Energy, Scientific and Engineering Services and Research Division

RRTAC's mission is to coordinate and foster reclamation research in Alberta. To this end, the Committee updates priorities, reviews research proposals, and organizes workshops.

1.1 PROGRAMS

RRTAC conducts research in four major program areas, which correspond to Alberta's major industrial activities and biophysical regions: Plains Coal, where agricultural concerns are dominant; Mountains and Foothills Coal, where recreation, forestry, wildlife and watershed concerns are the focus; Oil Sands, where wildlife and forestry concerns exist; and, Oil and Gas, where agricultural and forestry concerns are examined.

While it is expected that research results will often have province-wide application, the division of the research among the four programs has proven helpful in identifying priorities and directions.

The objectives of the research projects are:

1. To develop methods that will make reclamation a more efficient and effective process;
2. To provide scientific data to enable sound decision making in the regulatory and operational reclamation stages; and,
3. To provide scientific data to evaluate the effectiveness of reclamation guidelines and criteria.

RRTAC research projects are trials for new technologies, and new proposals are reviewed and rated on their adherence to priorities, likelihood of success and competence of researchers. Throughout the review process, the key question is: "Would this information make reclamation in Alberta a more efficient process?"

1.2 MANAGEMENT AND FUNDING

Every effort is made to involve industry in management and funding of the research to ensure the projects address real field concerns. Cooperation with industry facilitates agreement on reclamation research priorities and early implementation of research results in operations and planning.

The following companies and agencies were involved with the design and management of RRTAC projects this year:

Agriculture Canada
 Alberta Agriculture
 Alberta Energy, Scientific and Engineering Services and Research Division
 Alberta Energy Resources Conservation Board
 Alberta Environment, Land Reclamation Division
 Alberta Environment, Wastes and Chemicals Division
 Alberta Environmental Centre, Environmental Technology Division
 Alberta Environmental Centre, Plant Sciences Division
 Alberta Forestry, Lands and Wildlife, Alberta Forest Service
 Alberta Forestry, Lands and Wildlife, Fish and Wildlife Division
 Alberta Forestry, Lands and Wildlife, Public Lands Division
 Alberta Power Limited
 Alberta Research Council, Terrain Sciences Division
 Bow Valley Industries Ltd.
 Cardinal River Coals Ltd.
 Crows Nest Resources Limited
 ESSO Resources Canada Ltd.
 Fording Coal Ltd.
 Gregg River Resources Ltd.
 Luscar Ltd.

Luscar Sterco (1977) Ltd.

Manalta Coal Ltd.

NOVA Corporation of Alberta

Obed Mountain Coal Company Limited

OSLO

Shell Canada Resources Limited

Smoky River Coal Ltd.

Suncor Inc.

Syncrude Canada Limited

TransAlta Utilities Corporation

The following agencies and companies provided additional research funding for RRTAC projects this year:

Alberta Environmental Centre
 Alberta Research Council
 Alberta Transportation and Utilities
 Suncor Inc.
 Syncrude Canada Limited

1.3 SIGNIFICANT EVENTS IN 1989

This year RRTAC initiated several new projects in response to the results of the Concord Scientific study on the Future Research Needs for Alberta. In addition, RRTAC devoted a considerable amount of time in developing a research plan that will be used to guide the Program until 1994. This plan was developed using the information generated from the Concord study, from research lists provided by the program committees, from Development and Reclamation Review Committee and Land Conservation and Reclamation Council requests, and from the needs identified by RRTAC members for their own Departments.

After review, it became readily apparent that there simply were not enough resources to address all these needs and priority areas were identified. The Program that resulted is outlined in Figure 1. There is flexibility built into the Program to allow for changes to address

PROGRAM	1989	1990	1991	1992	1993
PCRRP	Effects of Perched Ponds on Groundwater and Salinity				
	Battle River Soil Reconstruction Project				
	Use of Spoil as Subsoil Material _____ >				
	Capability in Reclaimed Agricultural Lands _____ >				
	Genesee Soil Quality _____ >				
MFRRP	Technology Transfer _____ >				
	Physical Properties of Reclaimed Soils				
	Salinity Screening of Native Grass Species				
	Reclamation of Disturbed Alpine Lands				
	Selection, Evaluation and Multiplication of Native Legumes				
OGRRP	Soil Criteria for Reclamation _____ >				
	Topsoil Depth _____ >				
	Development of Sediment Modelling Database				
	Documentation of Successful Reclamation Practices				
	Compaction on Oil & Gas Leases (Costs covered by AEC _____ >)				
OSRRP	Literature Review on Drilling Waste Burial				
	CPA Sump Chemistry Study _____ >				
	Landfarming of Invert Drilling Wastes _____ >				
	Development of Soil Sterilants Reclamation Manual _____ >				
	Restoration of Mixed Grass Prairie Disturbed by Pipeline Construction - >				
GENERAL	Drilling Waste Disposal on Class 1-4 Lands				
	Soil Handling in Luvisols _____ >				
	Physical Properties of Reclaimed Soils				
	An Analysis of Vegetation Data from Reclaimed Oil Sands Areas				
	Oil Sands Soil Reconstruction Project				
GENERAL	Dewatering of Tailings Sludge _____ >				
	Effective Capping Depths for Tailings Sand _____ >				
	Update of Plant Species Suitability Manual				
	Review of Erosion Control Materials & Methods				
	Effects of Storage on Topsoil Quality				
GENERAL	User Guide to Pit & Quarry Reclamation in Alberta				
	Physical Properties in Reclaimed Land				
	Publications _____ >				

Figure 1. Five Year Research Plan

special needs not in the list, or to allow us to place more emphasis on some of the needs in the list. The start and completion dates for projects are similarly flexible. Wherever possible, those projects for which industry funding is available will be addressed first. With the development of a 5-year program we have made a decision not to accept unsolicited proposals. We recognize that many people outside of the RRTAC system have excellent research ideas, however our limited resources must be carefully allocated in order to meet our long-term goals, and thus funding of unplanned research ideas is not possible.

RRTAC's field based studies will be moving away from intensive plot work towards more operationally oriented, large-scale demonstration studies. This shift in emphasis will ensure that research results are more directly applicable to the day-to-day operational capabilities of the various companies, rather than being representative of what can be accomplished in a highly controlled plot.

The RRTAC Chairman presented papers on RRTAC goals and functions at several conferences, workshops and seminars this year. In addition, several papers arising from RRTAC funded projects were presented during the year. These efforts are an important method of communicating RRTAC activities to Albertans and others, and will be increased in the future.

Finally, RRTAC sponsored a major international reclamation conference held in Calgary, in August, by publishing the 800 page proceedings. Speakers from Alberta, Ontario, the United States, Great Britain, Germany, Brazil, Greece, Australia and South Africa, among others, presented the latest reclamation information to over 250 delegates.

1.4 REPORTS

Upon project completion, a final report is submitted. Some are published intact as RRTAC Reports and released to the public. Others are held, pending their inclusion in comprehensive RRTAC Reports. Since 1978, RRTAC has produced over 55 reports and workshop proceedings on a wide variety of topics. The reports are available at a small cost from Publication Services, Queen's Printers, 11510 Kingsway Avenue, Edmonton, Alberta T5G 2Y5. Section 9 provides a listing of available reports.

RRTAC made a decision to switch to recycled stock for all of its reports, starting with RRTAC 89-3. This step was taken in recognition of the increasing volume of paper used by the program and the public's growing environmental awareness and desire for the government to lead the way in environmental protection.

1.5 CONTENTS OF THIS REPORT

Following is a summary of the most recent research projects as of March 31, 1990. Budget details are given in Section 8. Information on previous projects is given in Section 7 and in previous annual reports.

Additional information on the Reclamation Research Program may be obtained by contacting:

Mr. Chris Powter, Chairman
Reclamation Research Technical Advisory Committee
3rd Floor, Oxbridge Place
9820 - 106 Street
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T5K 2J6
Telephone: (403) 427-4147

Plains Coal Reclamation Research Program



Members: Chris Powter (Chairman) - Alberta Environment; Lilli Chevri, r (Secretary) - Alberta Environment; Yae Moon Chae - Alberta Environment; John Dormaar - Agriculture Canada; Katherine Gizikoff - Manalta Coal Ltd.; John Hastie - TransAlta Utilities; Richard Johnson - Alberta Environmental Centre; Jivan Kayande - Alberta Power; Chong Ko - Alberta Environment; Dermot Lane - Fording Coal Ltd.; Bob Logan - Luscar Ltd.; Leon Marciak - Alberta Agriculture.

2. **PLAINS COAL RECLAMATION RESEARCH PROGRAM**

The Plains Coal Reclamation Research Program (PCRRP) has been designed by the provincial government and members of the coal industry to answer questions relating to groundwater and soil reconstruction in plains coal mining zones. Efforts are focused in two main areas:

1. Soil reconstruction will indicate how to rebuild agricultural soils after mining; and,
2. Hydrology will describe what happens to groundwater during mining and after reclamation, and how to rebuild the landscape to maximize the agricultural potential.

The Program has been jointly managed by the provincial government and coal industry personnel.

2.1 **RECLAMATION OBJECTIVES**

To return cropland to pre-mining levels of capability which includes both agricultural and hydrologic capabilities.

2.2 **THE PROBLEM**

Coal is surface mined in two major zones in Alberta: the Ardley Zone running southeast from Mayerthorpe to Red Deer, and the Horseshoe Canyon Zone which runs parallel and to the east from Barrhead through Camrose to Drumheller (Figure 2). The Ardley Zone is surface mined near Lake Wabamun to provide coal to the Wabamun, Sundance, Keephills, and Genesee power plants. The Horseshoe Canyon Zone is mined on either side of the Battle River between Forestburg and Halkirk. These mines supply the Battle River Generating Station. Another power plant and mine have been developed to the south of Sheerness.

Plains coal seams are usually overlain by bedrock which contain a high proportion of swelling clays. When exposed to the elements, the bedrock shales and sandstones break down into a material that is sticky when wet and very hard when dry. This severely hinders plant growth and agricul-

tural operations. Above the bedrock lie glacial deposits which are usually free of the most adverse properties of the bedrock though they lack the plant nutrients and organic matter which are characteristic of the overlying topsoil.

Rebuilding a soil profile is one of the major problems in cropland reclamation in Alberta. A soil must be built on levelled overburden which will have similar capability to the original soil. Existing evidence indicates that placing topsoil and a buffering material over the spoil is the most efficient method for achieving this goal (Figure 3). When topsoils or subsoils are in short supply, other materials may be useful in constructing a suitable rootzone medium. In addition to soil reconstruction, certain agricultural practices like green manuring and legume cropping may help rebuild the soil.

In many plains areas, the coal seams are the major source of domestic water. What will happen when the coal is removed and overburden fills the mined-out pit? The behaviour of the post-mining groundwater system will affect water users and could influence future agricultural potential. However, prior to the Plains Coal Reclamation Research Program, little was known about the effects of surface mining on groundwater in Alberta.

2.3 **RESEARCH FOCUS**

Work in 1989 focused on the use of alternate materials for soil reconstruction, and on the relationships between surface and subsurface water and soil quality.

2.4 **SOIL RECONSTRUCTION**

Battle River Soil Reconstruction Project - L. Leskiw. CAN-AG Enterprises Ltd.

Grain and forage yields were evaluated on a series of soil reconstruction plots in the Battle River mining area from 1982 to 1987.

Status: The project is completed and a five-year summary report has been published: RRTAC 89-5. The plots were fallowed in 1989 and will be replanted to forages in 1990 to allow for potential collection of data at a later date.

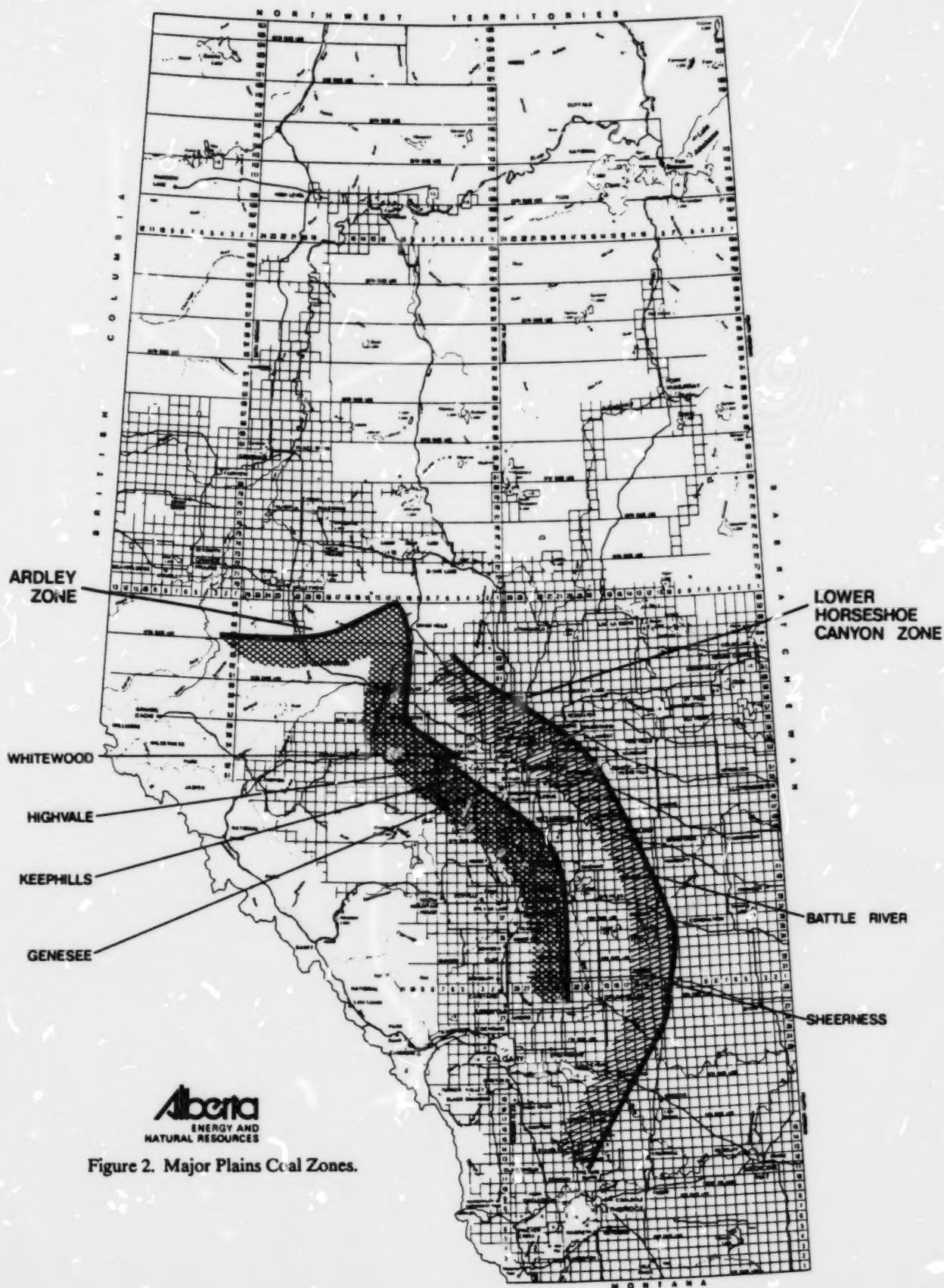
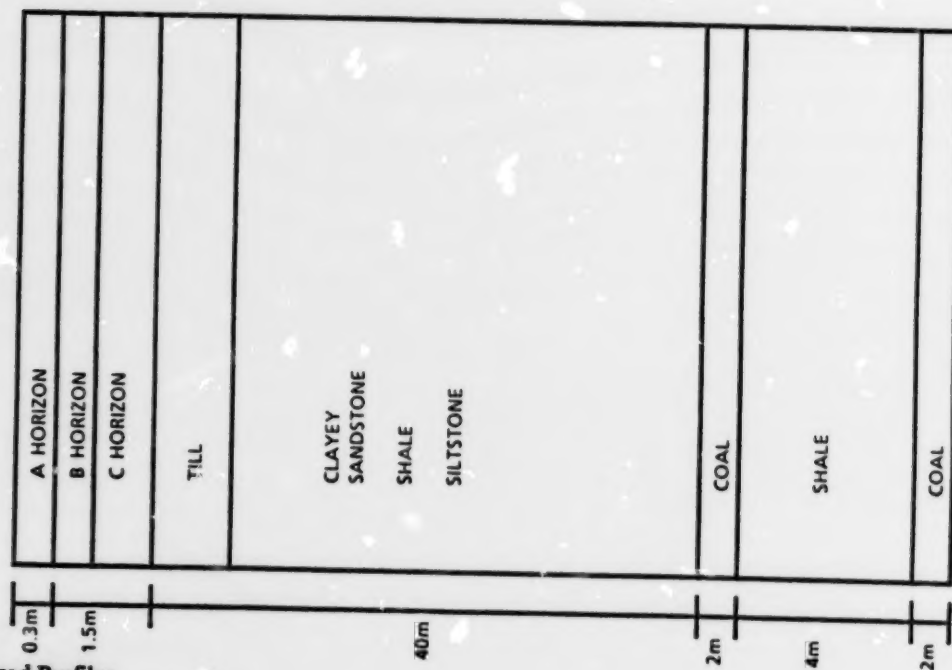


Figure 2. Major Plains Coal Zones.

PREMINING



RECLAIMED

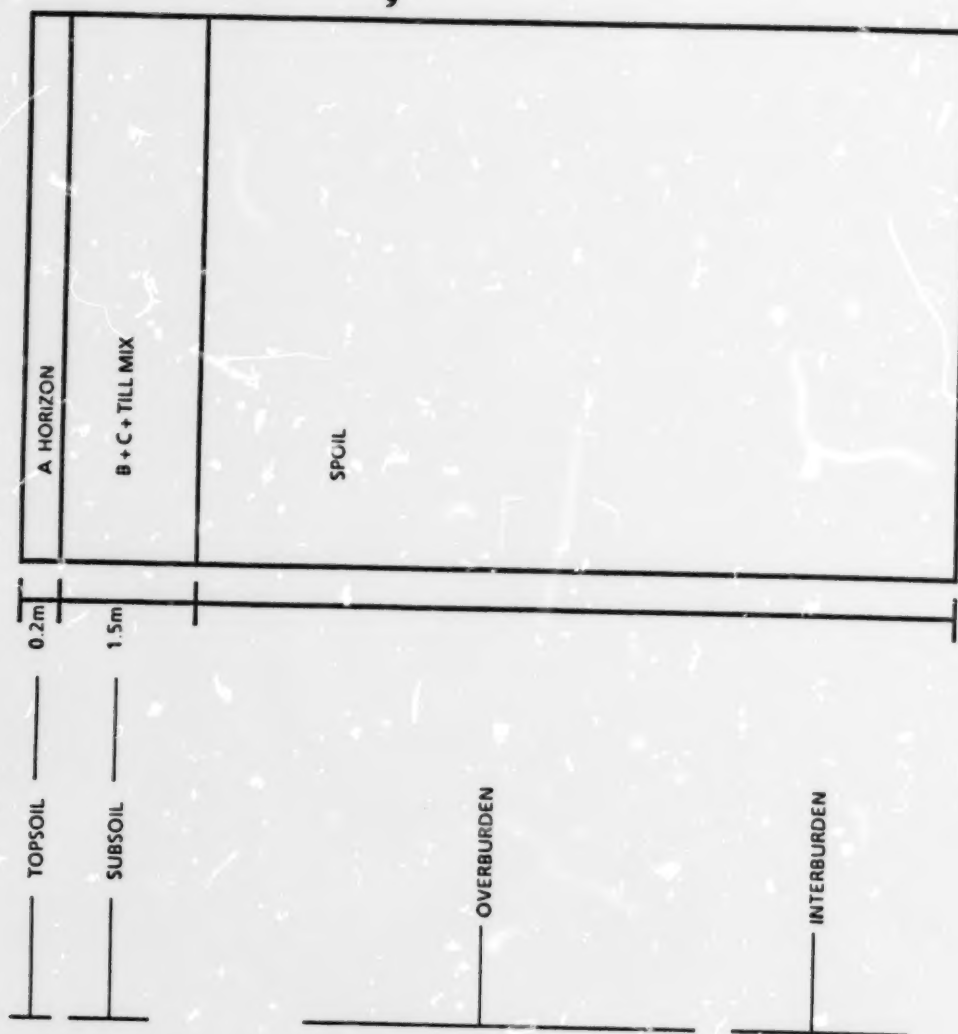
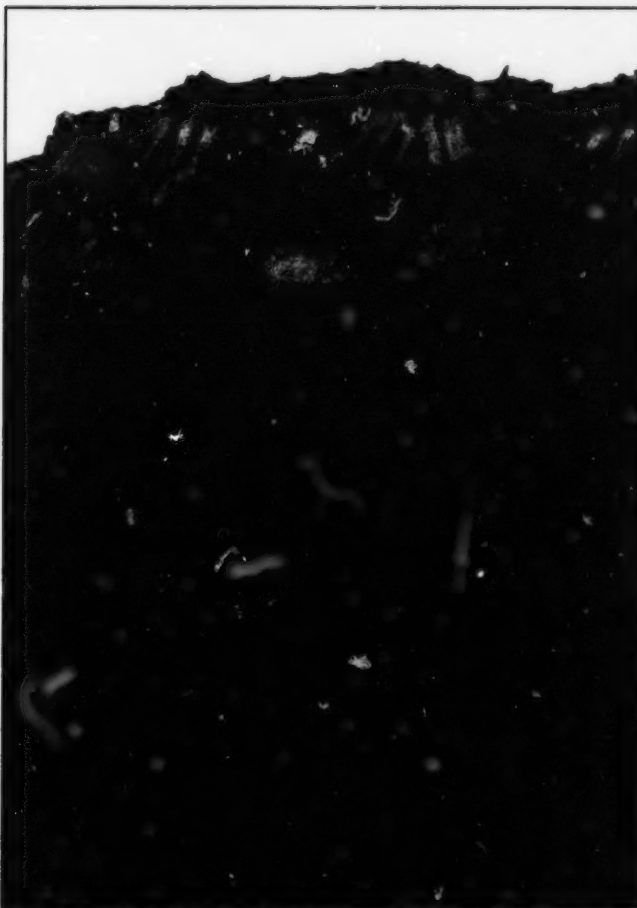


Figure 3. Generalized Profiles.

**Use of Spoil as Subsoil Material - T. Schori,
Monenco Consultants Limited and D. Chanasyk,
University of Alberta, Soil Science Department**

When crop lands are reclaimed, the minespoil is returned to the mine pit, then a layer of subsoil is replaced to a depth that will allow return of capability, and covered with the available topsoil. The replaced subsoils usually come from the first metre to metre-and-a-half of material under the topsoil. However, there are some cases where the material below this (up to several metres in depth) may be suitable for use as subsoil according to some commonly used criteria (texture, salt content, pH). Such is the case at the Highvale Mine and the Genesee Mine, west of Edmonton.

The objectives of this project are:



Highvale Subsoil Study. Various types of soil materials are available for reclamation.

1. To determine if sandy spoil materials at the Highvale Mine are suitable for use as subsoil material, and
2. To determine the need for modification of the Alberta Soil Quality Criteria for subsoil.

The study reviewed the existing database on chemical and physical characteristics of the materials and evaluated the moisture holding capabilities of the subsoils in the laboratory using lysimeters. As a result of these analyses, a detailed scope of work for a field study to further evaluate these materials was developed.

Status: The project is ongoing and is being co-funded by TransAlta Utilities Corporation.

2.5 WATER RELATIONS

**Plains Hydrology and Reclamation Project
- S.R. Moran, Alberta Research Council**

This study examined the impacts of surface mining on the regional groundwater, geology and soils. The main objectives included the identification of:

1. changes in groundwater quality and quantity after mining;
2. sources and release rates of salts to groundwater;
3. changes in distribution of groundwater after mining (Will the watertable drop or will it re-establish at pre-mining levels?);
4. changes in soil chemistry as a result of groundwater return; and,
5. surface stability after mining (subsidence, piping).

Critical groundwater and geologic parameters were identified which allow us to predict the "reclaimability" of a site prior to mining. This project began in 1979 and was conducted in the Battle River and Highvale mining areas.

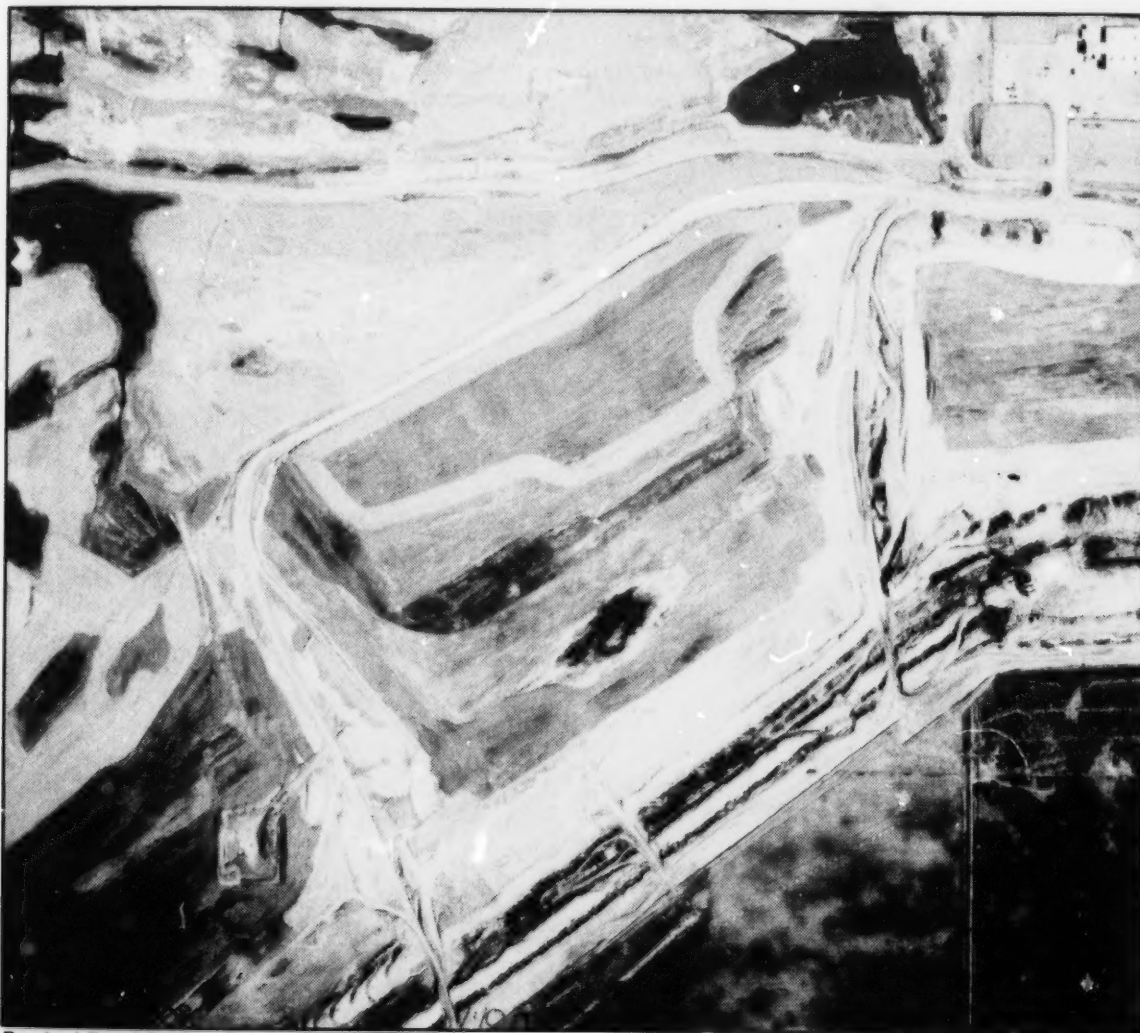
Status: The Alberta Research Council continues to conduct work under its own funding. Approximately 25 research reports are expected to be generated from this research project, including a summary report. Several reports have already been released: RRTAC 86-2, 86-3, 86-4, 86-5, 86-7, 87-9, 87-10, 87-11, 87-12, 87-13, 88-2, 88-4, 88-9, 88-12, 89-3, 89-7.

Effects of Perched Ponds on Groundwater and Salinity - S. Moran, Alberta Research Council

The objective of this study is to determine the potential effects of perched ponds in reclaimed plains coal mine sites on agricultural capability.

A monthly recorder was installed on the staff gauge at a pond at the Vesta Mine to allow a better understanding of a) the response of the pond to precipitation events, and b) the dynamics of water within the depression.

Soil moisture access tubes were monitored through to October using a moisture-density probe. In addition, soil moisture access tubes at unponded sites in the reclaimed land at Vesta were monitored (as controls).



Perched Pond Study. False-colour infrared photograph showing the western end of Vesta Mine on July 8, 1985. The dark oval shape patch near the center of the photograph is the perched pond S195.

Soil samples were taken at sites at 15 cm intervals for the first metre, and 30 cm intervals there after, to a depth of three metres and analyzed for saturation-paste extract salinity and EC.

Status: A final report documenting the hydrodynamics of the perched pond will be completed in 1990.

Water Balance in Sodic Spoil - R. Johnson,
Alberta Environmental Centre

Work conducted by the Alberta Research Council has shown that depth of the watertable in a saline sodic soil system can have a great effect on the quality of the rooting zone soil.

This study was initiated in 1986 to determine the effects of crop type, depth to groundwater and microclimate on salinity and water movement in reclaimed soils. Large lysimeters (75 cm wide x 100 cm deep) were developed at the

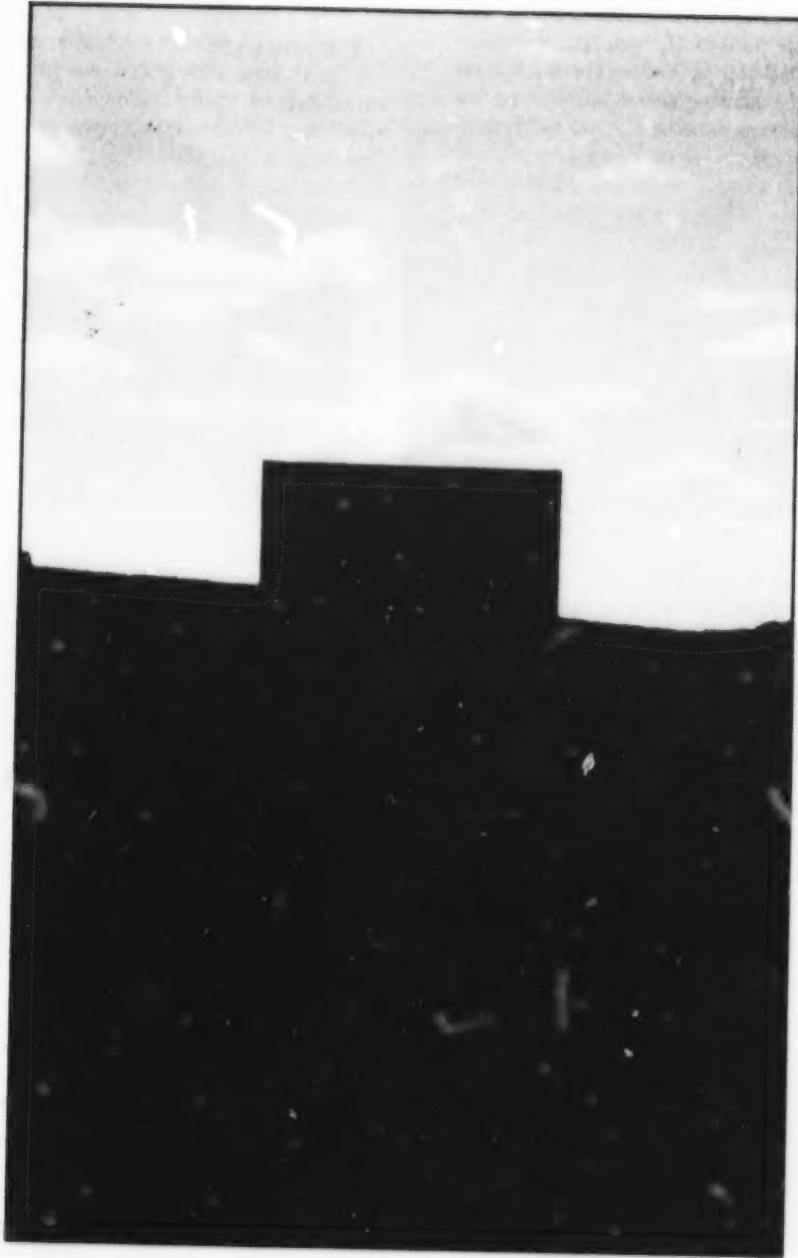
Alberta Environmental Centre and were planted to annual grain (barley or wheat), forage (alfalfa) or left fallow. One half of the lysimeters have a watertable maintained at 95 cm, the others are free draining.

The data collected over the life of the study will allow development of a model that can predict soil moisture content and movement over large areas with few data inputs. This will allow land managers to predict optimum locations for crops on a reclaimed landscape and to predict the effects of those crops on soil water balance.

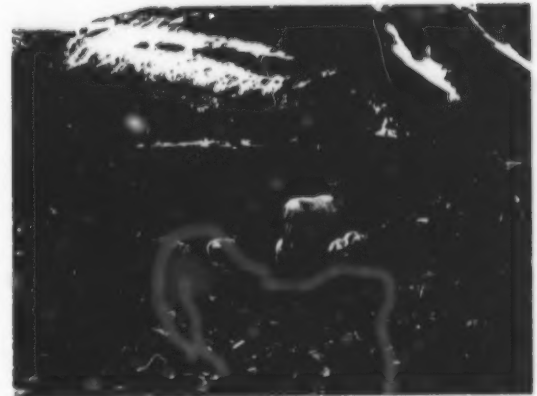
Status: The project is ongoing and is being funded by the Alberta Environmental Centre. More information is available in AEC annual reports.



Sodic Spoil Study. Lysimeters are shown planted with three different crops. The large poles have manometer tubes attached to measure changes in soil water content.



Mountains and Foothills Reclamation Research Program



Members: Chris Powter (Chairman) - Alberta Environment; Lilli Chevrier (Secretary) - Alberta Environment; Gerald Acott - Cardinal River Coal; Marcellus Adamkewicz - OBED Mountain Coal; Vernon Betts - Smoky River Coal Ltd.; Jeff Bondy - Forestry, Lands & Wildlife; Curtis Brinker - Luscar Sterco; Rick Ferster - Luscar Ltd.; Reinhard Hermesh - Alberta Environmental Centre; Al Kennedy - ESSO Resources; David Lloyd - Forestry, Lands & Wildlife; Bernd Martens - Manalta Coal Ltd.; Marlin Murphy - Gregg River Resources Ltd.; Tom Sneddon - Alberta Energy; Sam Takyi - Forestry, Lands & Wildlife; Don Townsend - Crows Nest Resources

3. MOUNTAINS AND FOOTHILLS RECLAMATION RESEARCH PROGRAM

In 1984, The Coal Association of Canada and RRTAC agreed to jointly fund and manage the Mountains and Foothills Reclamation Research Program (MFRRP). Over a period of five years the program addressed a number of issues that were applicable to mines throughout the region. Upon completion of those efforts, MFRRP agreed that future projects were likely to be of use to a much smaller group of mines (i.e., be site specific). Therefore, it was agreed that the program committee would continue to function in a review capacity, but that industry funding for future projects would likely come from individual mines, rather than from the Association.

3.1 RECLAMATION OBJECTIVES

1. Control of erosion on a variety of disturbances including coal mines, mineral exploration sites, and coal ash pits;
2. Return of forested lands to previous levels of capability; and,
3. Return of wildlife range to previous levels of capability.

3.2 THE PROBLEM

Reclamationists in the mountains and foothills face a wide variety of conditions. While some foothill sites are characterized by subdued terrain and moderate climate, other sites, particularly in the mountains, present steep slopes, rocky spoil and a short growing season. On these problem sites, summer droughts, chinook winds, erodible slopes and nutrient-poor soils are common.

On lower elevation foothill sites, reclamation is expected to yield forests with commercial potential while on the higher elevation mountain sites erosion control, and development of wildlife habitat and recreation potential are the reclamation objectives.

Reclaimed land in the mountains and foothills will not be as intensively managed as reclaimed agricultural lands would be. Also, topsoil and subsoil layers tend to be thin and difficult to handle selectively. Nonetheless, they are a valuable source of plant nutrients. So while some mixing of horizons is inevitable, how much is acceptable? How thick should the replaced soil layer be? Should the scarce topsoil be replaced evenly over the whole site, or in "islands" to provide a better growing medium in certain, designated areas? Other sites simply have no salvageable topsoil, and reclamation must prepare the site so that a plant-soil system will develop which will perform its land use expectations without indefinite fertilization.

3.3 RESEARCH FOCUS

There are four important aspects to reclamation in the mountains and foothills region:

1. The creation of stable reclaimable landscapes. This includes dump design (optimal slope, angles and lengths, terracing) and pit backfilling.
2. Preservation of watershed integrity and water quality. Water flow and sediment control are of prime interest.
3. Reconstruction of a suitable growing medium for each land use. The goal is to make the best use of limited materials to improve the rootzone over rocky, nutrient poor spoil.
4. Selection of suitable vegetation for each land use and proper planting to ensure survival and growth. The goal is creation of a self-sustaining cover that does not require long-term maintenance.

Work in 1989 focused on the selection of suitable plant species for the region, and on evaluating reclamation concerns for alpine lands.

3.4 REVEGETATION

Selection of Native Grasses for Reclamation - R. Hermesh, Alberta Environmental Centre

Many alpine and subalpine sites are difficult to reclaim simply because commercially available grasses and legumes either cannot survive or cannot reproduce in the short growing season. Where a long-term, maintenance free vegetation is the desired reclamation goal, both of these characteristics are crucial to success.

This study has selected lines of native grasses which are known to invade disturbances in sub-alpine and alpine areas. Selections were made both on the basis of commercial potential and fitness of reclamation. The selected varieties are now in the process of being registered. They will be made commercially available and will be suitable for the reclamation of disturbances (including, perhaps, degraded rangeland) in Alberta's Eastern Slopes region.

Status: The project is ongoing and is being funded by the Alberta Environmental Centre. More information is available in AEC annual reports.

Salinity Screening of Native Grass Species - A. Smrecl

The objective of the work was to determine salinity tolerance of various lines of native wheatgrasses and alpine bluegrasses selected in the above project.

The work involved:

1. Screening approximately 1000 lines of alpine bluegrass for salinity tolerance and selecting tolerant lines.
2. Reconfirming the salinity tolerance of selected lines by repeating the screening tests.
3. Propagating the selected lines and repeating the tests on the progeny to see if tolerance is an inherited character.

Status: The project is completed and a final report will be available in 1990.



Native Grass Project. Harvesting native grass lines at the Alberta Environmental Centre, Vegreville.

3.5 GENERAL

Reclamation of Disturbed Alpine Lands -
R. Parker, Hardy BBT Limited

Alpine ecosystems are extremely sensitive to disturbance and will require special efforts if they are to be successfully reclaimed. The objective of this study was to collect information from North American sources and to prepare a report that will summarize the measures needed to

reclaim alpine disturbances. The report will also point out the areas of research needed to fill information gaps for reclamation of alpine disturbances in Alberta. The assistance of the Canadian Parks Service in reviewing the report is greatly appreciated.

Status: The project is complete and a final report will be available in 1990.



Disturbed Alpine Lands Project. Native grass trial at Lookout Mountain on Sunshine Village ski slopes.

Oil Sands Reclamation Research Program



Members: Chris Powter (Chairman) - Alberta Environment; Lilli Chevrier (Secretary) - Alberta Environment; Tony Dai - Syncrude Canada Ltd.; Al Fedkenheuer - NOVA Corporation of Alberta; Al Kennedy - ESSO Resources; Paul Layte - Alberta Environmental Centre; Doug Mead - Shell Canada Resources Limited; Sam Takyi - Forestry, Lands & Wildlife; Steve Tuttle - Suncor Inc.

4. OIL SANDS RECLAMATION RESEARCH PROGRAM

In order to pool resources and avoid duplication of effort, RRTAC and industry initiated a joint research program in 1979. Priority research areas included woody plants (propagation, establishment and management) and soil reconstruction. In 1986, the Program was expanded to include reclamation of tailings pond sludges.

Syncrude Canada Ltd. and Suncor Inc. have been very active supporters of this Program, providing research facilities and funds.

4.1 RECLAMATION OBJECTIVES

1. To develop techniques whereby a self-sustaining, erosion-free cover can be established on oil sand tailings pond dykes; and,
2. To return tailings sand storage and overburden dumps to productive forest.

4.2 THE PROBLEM

Northeast Alberta contains all of Canada's surface-mineable oil sands. Extraction of this valuable petroleum resource presents several problems for reclamation. By far, the greatest problem lies with the tailings disposal systems currently employed.

At the end of its 25-year life, a typical oil sand plant producing 19 900 cubic meters per day (125 000 barrels per day) of synthetic crude oil will require a 22 to 31 square kilometre (8.5 to 12 square mile) tailings pond. The liquid contents of the pond will consist primarily of 360 million cubic meters of sludge. The sludge will remain in a liquid state indefinitely and will be impounded behind dykes built of tailings sand. (For more information on tailings ponds the reader is directed to a paper by M.D. MacKinnon in the AOSTRA Journal of Research, Volume 5: 109-133 (1989) titled Development of the Tailings Pond at Syncrude's Oil Sands Plant: 1978-1987).

The dykes are built from tailings sand, and will reach heights of 55 to 100 metres above ground level. Erosion protection on the dykes will be

provided by a cover of grasses, legumes and shrubs. Because the tailings sand is devoid of nutrients and drains rapidly, amending materials (muskeg, certain mineral overburdens) will be added to begin development of a soil.

Pits left after mining will be filled with tailings sand and overburden dumps will be constructed. These sites will also be reclaimed to a designated land use. Soil reconstruction and woody plant establishment in particular need further research.

4.3 RESEARCH FOCUS

As in the mountains and foothills, proper reclamation in Northeast Alberta will produce landform and plant community combinations which will fulfil their land use requirements without indefinite maintenance.

Work in 1989 continued to identify the best woody species to plant in reclamation areas and to identify the best soil amendments for tailings sand. We also evaluated the types of plant species that were invading reclaimed areas to determine how much we could count on natural processes to aid industry efforts.

Biological (plant species) and physical (slope, sand/sludge mixtures, freeze/thaw cycles) methods for dewatering tailings pond sludge are also being investigated. By dewatering sludge, a material with considerably less volume and with better engineering (trafficability) properties is created.

4.4 REVEGETATION

Oil Sands Soil Reconstruction Project - C. Warner, Hardy BBT Limited

Field trials were established on a 7 ha pad of tailings sand prepared by Syncrude Canada Ltd. on their property north of Fort McMurray (Figure 4). Various mixtures of peat and clay were incorporated to 20 and 40 cm depths. In 1984, the plots were planted with tree and shrub species to identify the best soil prescription for a particular forest cover type.

Oil Sands Reclamation Research Program



Members: Chris Powter (Chairman) - Alberta Environment; Lilli Chevrier (Secretary) - Alberta Environment; Tony Dai - Syncrude Canada Ltd.; Al Fedkenheuer - NOVA Corporation of Alberta; Al Kennedy - ESSO Resources; Paul Layte - Alberta Environmental Centre; Doug Mead - Shell Canada Resources Limited; Sam Takyi - Forestry, Lands & Wildlife; Steve Tuttle - Suncor Inc.

4. **OIL SANDS RECLAMATION RESEARCH PROGRAM**

In order to pool resources and avoid duplication of effort, RRTAC and industry initiated a joint research program in 1975. Priority research areas included woody plants (propagation, establishment and management) and soil reconstruction. In 1986, the Program was expanded to include reclamation of tailings pond sludges.

Syncrude Canada Ltd. and Suncor Inc. have been very active supporters of this Program, providing research facilities and funds.

4.1 RECLAMATION OBJECTIVES

1. To develop techniques whereby a self-sustaining, erosion-free cover can be established on oil sand tailings pond dykes; and,
2. To return tailings sand storage and overburden dumps to productive forest.

4.2 THE PROBLEM

Northeast Alberta contains all of Canada's surface-mineable oil sands. Extraction of this valuable petroleum resource presents several problems for reclamation. By far, the greatest problem lies with the tailings disposal systems currently employed.

At the end of its 25-year life, a typical oil sand plant producing 19 900 cubic meters per day (125 000 barrels per day) of synthetic crude oil will require a 22 to 31 square kilometre (8.5 to 12 square mile) tailings pond. The liquid contents of the pond will consist primarily of 360 million cubic meters of sludge. The sludge will remain in a liquid state indefinitely and will be impounded behind dykes built of tailings sand. (For more information on tailings ponds the reader is directed to a paper by M.D. MacKinnon in the AOSTRA Journal of Research, Volume 5: 109-133 (1989) titled Development of the Tailings Pond at Syncrude's Oil Sands Plant: 1978-1987).

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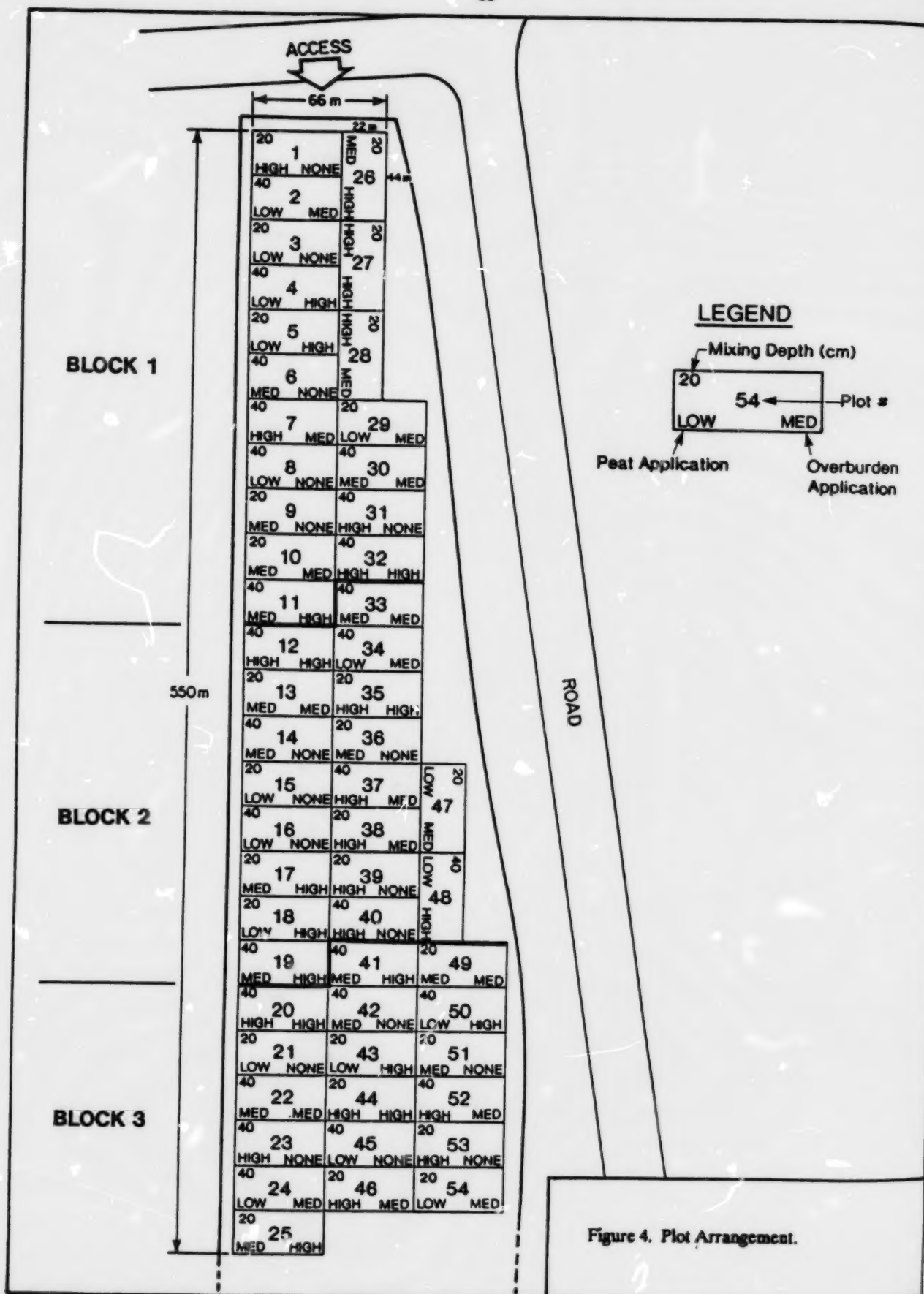


Figure 4. Plot Arrangement.

Data were collected for five years on tree/shrub survival, growth and spread, and on soil moisture and soil nutrients.

The project was jointly funded with Syncrude Canada Ltd. and Suncor Inc.

Status: The data collection has been completed. A final report will be written in 1990.

An Analysis of Vegetation Data from Reclaimed Oil Sands Areas - C. Warner, Hardy BBT Limited

Current methods of revegetating reclaimed areas generally include capping with a peat overburden mixture, seeding with a grass legume mixture, barley nurse crop, or no seeding, and then planting with trees and shrubs. Fertilizer is applied at the time of seeding and for a period of up to three or more years thereafter.

The long-term reclamation goals of these operations are the reestablishment of vegetation communities that are self-sustaining, compatible with the pre-disturbed terrain, and consistent with the end land use of non-commercial forest production providing habitat for wildlife and opportunities for recreation. In addition, an important short-term reclamation goal is providing erosion

control, particularly on tailings dyke slopes.

The main objectives of the study were to document the species composition and rate of natural invasion into reclaimed areas and to determine the influence of reclamation methods (seeding, fertilizing, amendment material, etc.) on composition and rate of invasion.

Information was gathered and data reviewed on vegetation establishment in reclaimed areas from both Suncor and Syncrude projects. The data were then synthesized to mean cover values for dominant species on a given site after 1, 5, 10 and 15 years.

Native species composition and rate of establishment for the Syncrude data from the following reclamation sites were compared:

1. Tailings sand seeded to agronomic grasses and legumes,
2. Tailings sand seeded to native grasses and legumes,
3. Tailings sand not seeded (or only seeded to barley),
4. Overburden seeded to agronomic, and



Vegetation Study. The combination of planted and invading species form a reclaimed area.

5. Overburden not seeded (or only seeded to barley).

Variations due to peat-overburden ratio were compared using data collected from the RRTAC Soil Reconstruction Project (see above).

Status: The project is completed and a final report will be available in 1990.

4.5 OIL SANDS SLUDGE

Biological Dewatering of Oil Sands Tailings - R. Johnson and P. Layte, Alberta Environmental Centre

Five years of research at AEC and Fort McMurray have established three important facts about the dewatering of oil sands sludges (or fines less than 22 microns in diameter):

1. it is possible to dewater pure oil sands sludge (as opposed to mixing sand and sludge);
2. freezing and thawing sludge will cause the solids content to increase from 30% to 50% (dry weight basis);

3. reed canary grass can be established on sludge at 50% solids, and the plants will dewater the sludge so that a stable, competent surface results (approximately 80% solids).

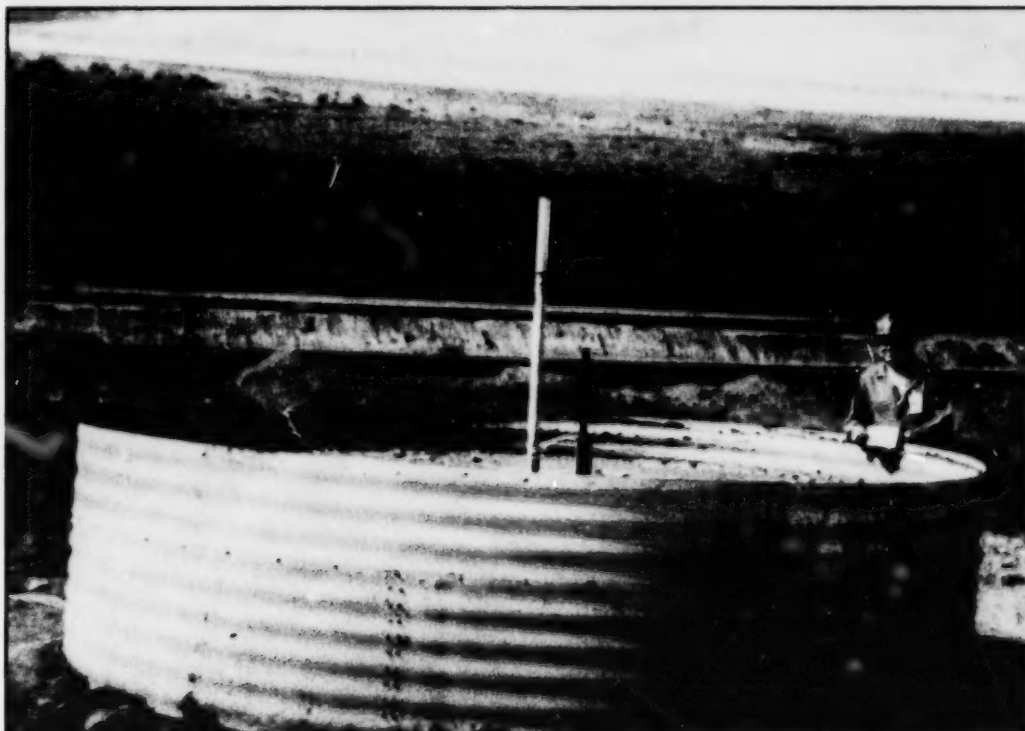
Two of three objectives set for the project in 1987 have now been met. First, the amount of dewatering of pure sludge that occurs as a result of freezing and thawing over winter has been established. Dewatering by freezing and thawing is dependent only on the initial solids content:

$$Y = 365.3 (0.93)^X$$

where Y = solids content after freeze-thaw

X = initial solids content

(For further information see: Johnson, R.L., P. Bork and P. Layte. 1989. The effect of freezing and thawing on the dewatering of oil sands sludges. IN: Proceedings of the Conference Reclamation, A Global Perspective. D.G. Walker, C.B. Powter and M.W. Pole (Compilers). Alberta Land Conservation and Reclamation Council Report # RRTAC 89-2).



Dewatering Study. The sludge in this grain bin was originally near the top of the white post; freeze-thaw and evaporation has reduced the sludge volume by about one-half.

Second, a surface drainage system for sludges has been constructed that is extremely simple, inexpensive and effective. Furthermore, it has been shown that surface drainage is absolutely essential; if the drainage system does not function properly and water is allowed to accumulate on the surface, originating from the thawing process or precipitation, plants will not establish and dewatering does not occur.

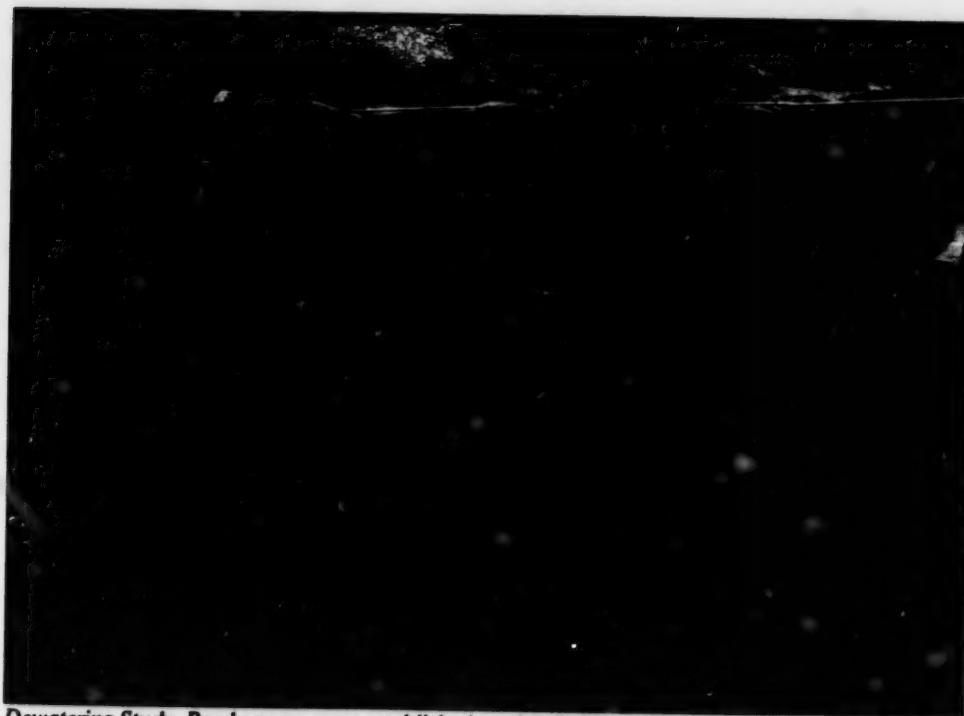
The third objective was to compare dewatering by plants (evapo-transpiration) and by evaporation alone. Due to the malfunction of the first attempts at surface drainage, this comparison has not been made. It is obvious, however, that dewatering by plants is faster and much deeper when the plants are established in the early summer (late May in Fort McMurray).

Both pure sludge, starting at 30% solids, and sand-sludge mixes, starting at 50% solids, have been successfully dewatered using a combination

of freezing and thawing, evaporation and evapo-transpiration. The surfaces can now support the pressure of equipment traffic. Volume reduction as a result of dewatering varies according to the starting materials. For the pure sludges, the final volume is only 35 to 40% of the original; for the sand-sludges mixes, the final volume is 65% of the original. The difference is due, of course, to the different amount of water contained in the two materials initially and the water loss during freezing and thawing and evapo-transpiration.

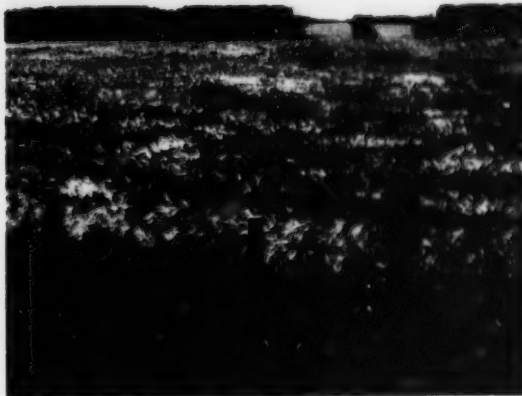
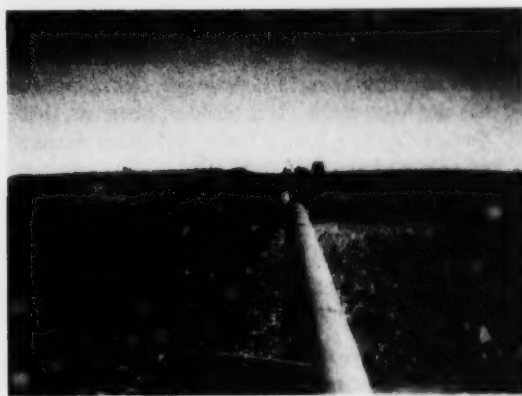
Reed canary grass has been shown to be hardy; it will overwinter in northeastern Alberta while growing on oil sands sludge.

Status: Work is ongoing at AEC. A final report on the work to-date will be completed in 1990.



Dewatering Study. Reed canary grass established on the sludge in the pits, but did better around the edges than in the wetter centre.

Oil and Gas Reclamation Research Program



Members: Chris Powter (Chairman) - Alberta Environment; Lilli Chevrier (Secretary) - Alberta Environment; Richard Coleman - Alberta Environmental Centre; Roger Creasy - Energy Resources Conservation Board; Al Fedkenheuer - NOVA Corporation of Alberta; Jim Fujikawa - Alberta Environment; Arnold Janz - Alberta Environment; David Lloyd - Forestry, Lands & Wildlife; Leon Marciak - Alberta Agriculture; Doug Mead - Shell Canada Resources Limited; Gary Mott - Bow Valley Industries Ltd.; Sam Takyi - Forestry, Lands & Wildlife.

5. OIL AND GAS RECLAMATION RESEARCH PROGRAM

Conventional oil and gas deposits are found in all three biophysical regions noted above, while heavy oil deposits are found in the northeast. Since these disturbance types create similar reclamation concerns (disposal of drilling wastes, compaction, soil handling, residual herbicides) regardless of biophysical region, a separate program was developed to co-ordinate research.

There are more than 130 000 wellsites and over 200 000 km of pipelines in the province, indicating the need for a strong research program in this area.

5.1 RECLAMATION OBJECTIVES

The Oil and Gas research program addresses reclamation of all types of oil and gas facilities, including: wellsites, on- and off-site drilling waste sumps, access roads, compressor stations and batteries, and pipelines. Specific reclamation objectives are:

1. To develop environmentally-safe methods for disposal of drilling wastes (fluids and solids); and,
2. To return land to a condition capable of sustaining an approved land use.

5.2 THE PROBLEM

5.2.1 Drilling Wastes

Three basic drilling muds and variations thereof are used for oil and gas exploration in Alberta. The freshwater gel bentonite is most commonly used followed by the salt water systems which use sodium or potassium. The oil invert drilling mud is also used and is gaining in popularity with some companies. Diammonium phosphate (DAP) mud is being used in the Cold Lake region.

The wastes produced from drilling operations contain many complex organic and inorganic compounds that are added at various stages of the drilling process. The materials that start out as drilling mud are usually extensively altered chemi-

cally and physically by the time they enter a waste pit. The muds can be altered by heat and pressure effects associated with drilling and by the addition of drill cuttings (rock) brought up with the mud system. The materials found in the waste pit can also be changed chemically and physically by other products that are purposely or inadvertently added to the pit. Caustic soda, rig wash, diesel fuel, waste oil from machinery, metal and plastic containers, and other refuse often find their way into a waste pit.

The physical location of the waste pits must be carefully chosen to minimize the potential for subsurface spread of leachates that may be generated from the drilling wastes. Knowledge of site characteristics such as: (1) the distance between the disposal site and the nearest surface water body, groundwater supply, or other designated boundary, (2) the depth to the watertable, (3) the water table gradient away from the site, and (4) the type and thickness of geologic material through which the contaminated water could migrate is required to make decisions on the suitability of a waste pit location. Knowledge of proposed waste pit contents and their likely effects on the permeability of pit liners is also important.

Drilling wastes are currently disposed of by burying, trenching, squeezing, and spreading. Each of these disposal methods impacts the environment in different ways. For example, interactions of waste constituents with groundwater is much more likely to occur if wastes are trenched or buried as opposed to surface spread. The reverse is true for soils and plants.

Review of the literature indicates that effects of disposal of drilling wastes on plants and soils varies with the type of waste, rate of application and plant species.

A thorough physical and chemical analysis of the liquid and solid phases of wastes generated by drilling operations utilizing the different mud types is one of the prerequisites to assessing the potential environmental hazard of the disposal of these wastes and developing environmentally safe disposal methods.

5.2.2 Compaction

Mining, pipelining and the construction of oil and gas leases all have dramatic effects on soil compaction. In fact, a recent report by the United States Office of Technology Assessment found that soil compaction was the single biggest problem in reclaiming cropland disturbed by mining. A survey conducted by the Pipeline and Wellsite sub-committee of RRTAC found that Reclamation Officers perceived soil compaction to be the prime concern in reclaiming oil and gas wellsites.

Repeated passage of heavy equipment during development and operating phases of a wellsite results in compaction of the soil. Compacted soil retards root development which can lead to moisture and nutrient stress in plants. This, in turn, retards shoot development and yield. Freeze/thaw and wetting/drying cycles were thought to loosen compacted soil, but current evidence suggests that their benefits are rather limited. In Alberta, moderately compacted soils can have recovery times measured in decades; high clay contents are associated with long recovery times.

There is a paucity of useful data pertaining to soil compaction in Alberta (and elsewhere), largely because a fully satisfactory measurement has yet to be identified. Crop yield is the best measure of compaction in addressing agricultural concerns. However, the effect of soil compaction on crop yield varies with soil type, yearly meteorological conditions, and type of crop. A measurement of compaction must be identified that has a high correlation with plant response, is independent of soil type, is inexpensive, and can be performed rapidly.

Bulk density is most commonly used to determine soil compaction but shows considerable natural variation due to soil particle size distribution and organic water content, and has no unique value at which root growth is impeded. Hydraulic conductivity, porosity, air permeability, infiltration and sorptivity yield valuable information about the effect of compaction on physical processes in soils. But these measurements are not used widely due to long measurement times, wide data variability, departure from normality and the absence of an exact relationship between these properties and plant growth.

A hand penetrometer, developed at the Alberta Environmental Centre, allows mechanical impedance to be measured at various depths in the field at extremely low cost. Now, Reclamation Officers are equipped to measure compaction at any disturbed site. However, there is little information relating mechanical impedance or any other measurement to reductions in crop yield in Alberta. What is needed is a simple model for routine applications that predicts plant yield with a minimum of data input.

It is important to note that while well-sites were chosen for evaluation of compaction problems, any disturbance that involves the use of heavy equipment can produce compaction. Thus, the results of this research may be applicable to pipelines, highways, mines, sand and gravel pits, and forestry skid trails and loading zones, among others.

5.2.3 Residual Herbicides

Soil sterilants, residual herbicides that render the treated soil unfit for plant growth for relatively long periods of time, are used in Alberta on wellsites, rights-of-way and other industrial areas for total vegetation control. Such vegetation control measures reduce fire hazards and improve aesthetic appearance. The treated areas can remain devoid of vegetation for many years depending upon the type and rate of soil sterilant used and the soil and climatic conditions. Furthermore, it is not uncommon to use more than the recommended rates of these chemicals for achieving long-term vegetation control with a single application. Bromacil and tebuthiuron are commonly used soil sterilants in Alberta.

Once the sterilant-treated site is abandoned, it may take several years before the site is restored to its original capability. The site also becomes a potential source of contamination through surface runoff and wind dispersion of soil sterilants onto adjoining untreated land. In Alberta, the extent of the soil sterilant problem is becoming apparent as more oil and gas lease sites are abandoned due to the marginal production value of many wells. The seriousness of the problem has been identified by various provincial organizations and committees.

5.3 RESEARCH FOCUS

In 1984, RRTAC sponsored a two-day workshop on drilling waste disposal in Alberta (Report 87-3). The workshop identified a number of concerns that needed to be addressed. As a result of this workshop, our initial research focused on trying to develop a manual that could be used by field staff to determine whether a waste could be safely spread on a given soil surface (Report 87-1). The manual pointed to a need for detailed chemical characterization of sump fluids and solids before rational disposal decisions could be made (Report 89-6). Work in 1989 concentrated on revising the original field disposal manual, getting more data on sump chemistry, and evaluating burial and landfarming as disposal options.

The approach to the compaction problem was to determine what characteristics predispose a soil to compaction and to identify the best field method for identifying and quantifying compaction. This knowledge will allow operators to avoid compaction wherever possible, and allow regula-

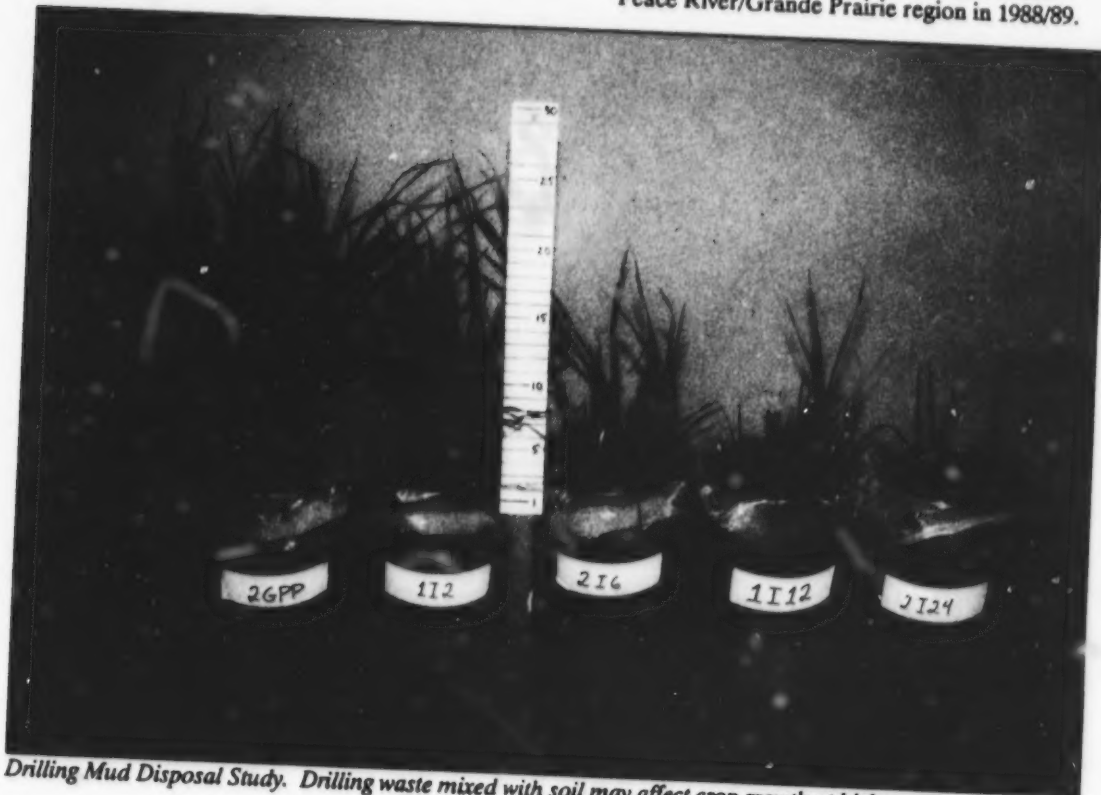
tory personnel to identify compacted areas. Work in 1989 continued to evaluate the effects of compaction on plants.

The approach to the residual herbicide problem was to identify methods for binding the herbicide, thus rendering it ineffective (Report 89-3). There was no work in this area in 1989.

5.4 DRILLING WASTES

Drilling Mud Disposal - T. Macyk, Alberta Research Council

The purpose of this project is to provide a scientific basis for development of guidelines for drilling mud solids disposal that optimizes environmental safety and cost effectiveness by carrying out problem analysis, and preliminary research to identify environmental limitations of available disposal technology. Drilling waste fluids and solids were collected from sumps at wellsites in the Cold Lake region (1986/87), the Eastern Slopes region in (1987/88), and the Peace River/Grande Prairie region in 1988/89.



Drilling Mud Disposal Study. Drilling waste mixed with soil may affect crop growth at higher waste rates.

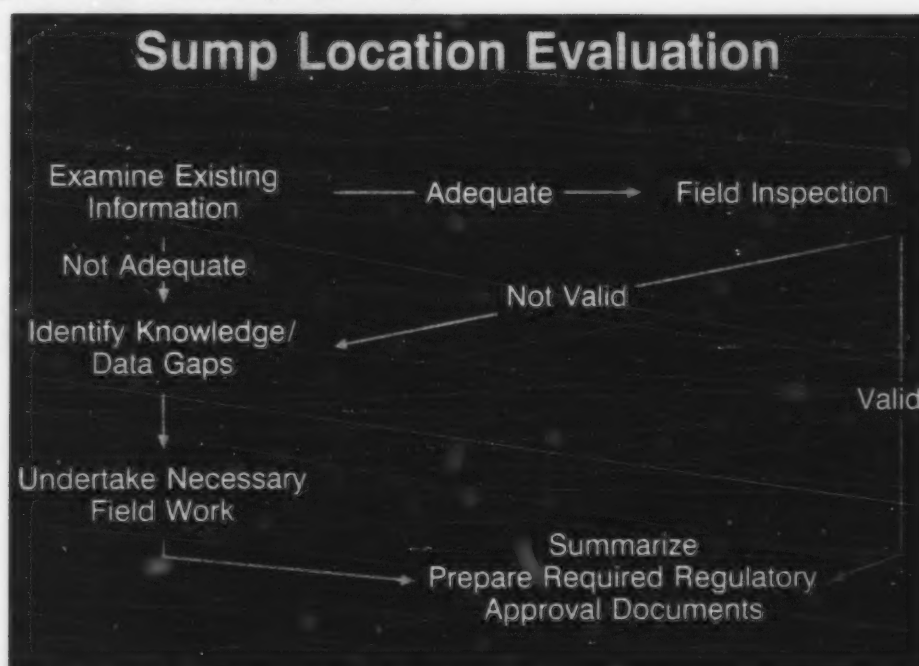
Samples were collected at several depths in each of several locations within a sump to determine spatial variability in the waste properties. A suite of chemical analyses was performed to characterize both solids and fluids. The sump solids were mixed at various rates with a soil indigenous to the respective region and planted to a grass species typically used in reclamation. The results of these greenhouse trials have provided preliminary indications of how much waste can be added to soil and still achieve acceptable reclamation.

In addition to the field study, a literature review was conducted to assess the effectiveness of geological containment of drilling waste in sumps.

staff in the planning and implementation of environmentally sound methods for surface disposal of drilling wastes.

The researchers will obtain comments on the original report from government and industry staff, and then will revise the original manual, specifically by:

1. developing a more definitive drilling waste disposal decision flow chart,
2. developing a glossary or simplifying terminology used in the manual,



Drilling Waste Manual. Steps to be followed in evaluating the suitability of a site for locating a sump.

Status: Project is completed. A report on the geological containment (clay liners) of drilling wastes has been published: RRTAC 88-10. A summary report for the three year field study has also been published: RRTAC 89-6.

Update of the Drilling Waste Disposal Manual - T. Marcyk, Alberta Research Council

The objective is to revise and update the existing RRTAC field manual (Report 87-1) prepared to assist industry and government field

3. indicating what parameters could be tested in the field, why they should be tested, and the appropriate procedures to be used,
4. redefining the calculations to determine sump contents; providing critical levels for parameters so that calculations are completed,
5. condensing and clarifying the checklist for fieldmen,

6. expanding on the guidelines for obtaining representative samples, and
7. developing a computer program that will allow users to do the calculations prescribed in the manual.

The study is being coordinated as much as possible with work ongoing in the government/industry Drilling Waste Review Committee that has responsibility for updating the existing drilling waste guidelines (see next project).

Status: The project is ongoing and is being co-funded with the Alberta Research Council.

**CPA Sump Chemistry Study - T. Masyk,
Alberta Research Council**

A joint government and industry task force is currently updating the existing guidelines/criteria for disposal of drilling wastes in Alberta. The Drilling Waste Review Committee decided that a sump sampling and analysis project was required to allow for characterization of a cross-section of drilling wastes from sumps throughout Alberta. The data from this study will enhance the work

already done by RRTAC and the Alberta Research Council (see above) and will provide a basis for the criteria that are ultimately developed.

The objective of this project was to design a study for the characterization of a cross-section of drilling wastes from sumps throughout Alberta. The study design included a number of specific components:

1. Sampling, including: number of sumps to be sampled; locations to be sampled; types of wastes to be sampled; and, sampling protocol.
2. Characterization, including analyses to be conducted and, methods specified for each analysis.
3. Building of database.
4. Data synthesis and interpretation.
5. Report preparation.

Status: The project is ongoing and is being co-funded by the Alberta Research Council.



CPA Sump Chemistry. One of the sampling methods proposed for the study.



Burial Study. Drilling waste burial is one disposal option.

Literature Review on the Environmental Acceptability of Drilling Waste Burial - T. Schori, Monenco Consultants Limited

Drilling waste solids may be disposed of in several ways: burying, trenching, squeezing, and landfarming. There has been a movement within some sectors of the government away from burying in sumps as a disposal option because of concerns about potential for migration of contaminants into groundwater.

The objective of this project was to review the international literature to determine the environmental acceptability of burial of drilling waste solids produced during petroleum exploration. One of the major tasks was to define, to everyone's satisfaction, the term burial, and the various forms it may take.

Status: The project is completed and a final report will be available in 1990.

Landfarming of Invert Drilling Wastes - T. Macyk, Alberta Research Council

Diesel fuel forms the liquid portion of invert drilling muds rather than water. Therefore, the organics in the waste may be biodegradable in the soil, and landfarming of this type of drilling waste may be an environmentally sensible option. This objective of this study is to develop an environmentally acceptable land application rates of invert mud drilling wastes for soils in Alberta and to model the fate of these wastes. The sub-objectives include:

1. measurement of the rates of degradation of the invert mud drilling wastes in soil at different waste concentrations, frequencies of application, and soil temperature;
2. measurement of the relative impact of oily materials and salts present in the wastes on soil quality and plant growth in a greenhouse pot experiment; and,

3. assessment of the impact of different application rates and frequencies of application of invert mud drilling wastes on soils and vegetation in a field experiment.

Petro-Canada has supplied the invert waste and a field location for the research near Edson. Local Alberta Forest Service officials have also been very helpful in the project.

Status: The project is ongoing and was co-funded by the Alberta Research Council in 1989/90.

Bulk density is most commonly used to determine soil compaction, but it shows considerable natural variation due to soil particle size distribution and organic matter content, and has no unique value at which root growth is impeded. Hydraulic conductivity, porosity, air permeability, infiltration and sorptivity yield more valuable information; however, they are restricted from widespread use due to the considerable measurement time involved, the wide data variability, departure from normality, and the absence of an exact relationship between these properties and plant growth.



Invert Study. Diesel invert drilling wastes in the sump (left) will be spread on-site at various rates.

5.5 COMPACTION

Compaction on Oil and Gas Leases (Phase I) - N. Finlayson, CAN-AG Enterprises Ltd.

The concern in compaction-related reclamation research is measuring variables which can influence root development below the cultivated zone and evaluating whether or not these variables are substantially different from those in nearby non-compacted soils.

Investigation of the relationship between soil mechanical strength, as measured by penetration resistance and plant root growth, indicates that a rapid, inexpensive measure of compaction may be available. Although soil strength is dependent on moisture content, texture, and soil fabric, the unambiguous relationship between soil strength, regardless of its cause, and root growth makes mechanical impedance a potentially valuable measurement of soil compaction.

Cone penetrometers are widely used for studies of soil trafficability and are now commonly used to measure soil compaction. The cone penetrometer has even been adopted by some for routine use in evaluating compaction problems in land reclamation. Perhaps slowing a more widespread use of penetrometers is a standardization problem. Penetrometer cones come in various shapes and sizes with results depending to some degree on the type of cone used. However, quantitative results from penetrometer cones of the same type produce consistent and comparable results. Penetrometer readings should be made at

1. The suitability of various methods of measuring compaction (soil strength, bulk density, morphology, porosity, pore size distribution) with regard to their sensitivity in detecting compaction, the number of samples necessary to adequately assess compaction, the time and cost involved, and the skill, equipment or facilities necessary to use the technique;
2. The extent of soil compaction, both vertically and horizontally;



Compaction Phase I. Compaction by vehicle traffic may pose future reclamation concerns.

some standard soil moisture, preferably field capacity which would identify the strength of least resistance to root growth. In this regard, readings taken in spring, late fall, or after heavy rainfall may prove most valuable, although readings under drier conditions may have equal merit if reasonable caution is exercised.

This field survey project addressed four compaction concerns on east central Alberta oil and gas wellsites:

3. The degree of soil compaction on oil and gas well lease sites as compared to adjacent off-site areas; and,
4. The nature of soil compaction with respect to how various soil properties are affected by the compaction process.

To accomplish these goals, a two-stage survey was conducted. A detailed survey concentrated on establishing appropriate sampling densities and on evaluating various techniques of measuring compaction. At five wellsites, data

were collected on soil strength (recording penetrometer), undisturbed cores were collected for measurement of bulk density and pore size distribution, disturbed or undisturbed cores were collected for measurement of moisture content, texture and organic matter, and soil profiles (for classification) and soil morphology (for the morphological compaction classification technique of McKeague et al.) were recorded.

The second part of the survey involved an assessment of soil compaction on 20 wellsites using a recording penetrometer to measure vertical and horizontal soil compaction profiles. Emphasis was placed on strength measurements because they can be taken quickly, no expensive and time consuming laboratory work is required, and work at the Alberta Environmental Centre and elsewhere suggests that soil strength may be the variable most closely related to plant growth in compacted soils.

The information generated by this research should better determine the nature and scope of the compaction problem and will establish appropriate methods and sampling designs for future work concerning compaction on Alberta oil and gas leases.

Status: This phase of the compaction work is completed and a final report is in preparation.

Compaction on Oil and Gas Leases (Phase II) - Milner Engineering

The main objective of this research is to identify the relationship between subsoil compaction, topsoil depth and plant productivity under a range of conditions (soils and years). The experiment is factorial and arranged in a completely randomized design, with three compaction levels (no compaction, medium, and heavy compaction) and four topsoil levels (5, 20,



Compaction Phase II. Compaction plots at the Alberta Environmental Centre in Vegreville showing the 1990 barley crop prior to biomass sampling.

35, and 50 cm depth). Each treatment is replicated four times at each of two sites: a Chernozem soil in Vegreville (Figure 5), which was constructed in 1989; and a Luvisol near Myrnam (Figure 6), which will be constructed in 1990. This gives a total of 96 plots. Barley is being grown in each plot for three years, and the growth response (measured by root biomass, root length, shoot biomass and crop yield) will be related to three measures of soil compaction (penetration resistance, bulk density and porosity). The null hypotheses are:

1. The degree of subsoil compaction does not influence barley growth or productivity (as measured by yield, biomass, or rooting characteristics) in fine-textured soils.
2. Barley growth and productivity on compacted, fine-textured soils is independent of topsoil depth.
3. The relationship between barley growth and productivity, and subsoil compaction is independent of soil type (Chernozem or Luvisol).
4. Barley growth and productivity on compacted, fine-textured soils is independent of climate (year).
5. There are no interactions between subsoil compaction, topsoil depth and climate (year) that influence barley growth or productivity on compacted, fine-textured soils.
6. Soil strength, bulk density and pore-size distribution are equally accurate in predicting barley growth and productivity in compacted, fine-textured soils.

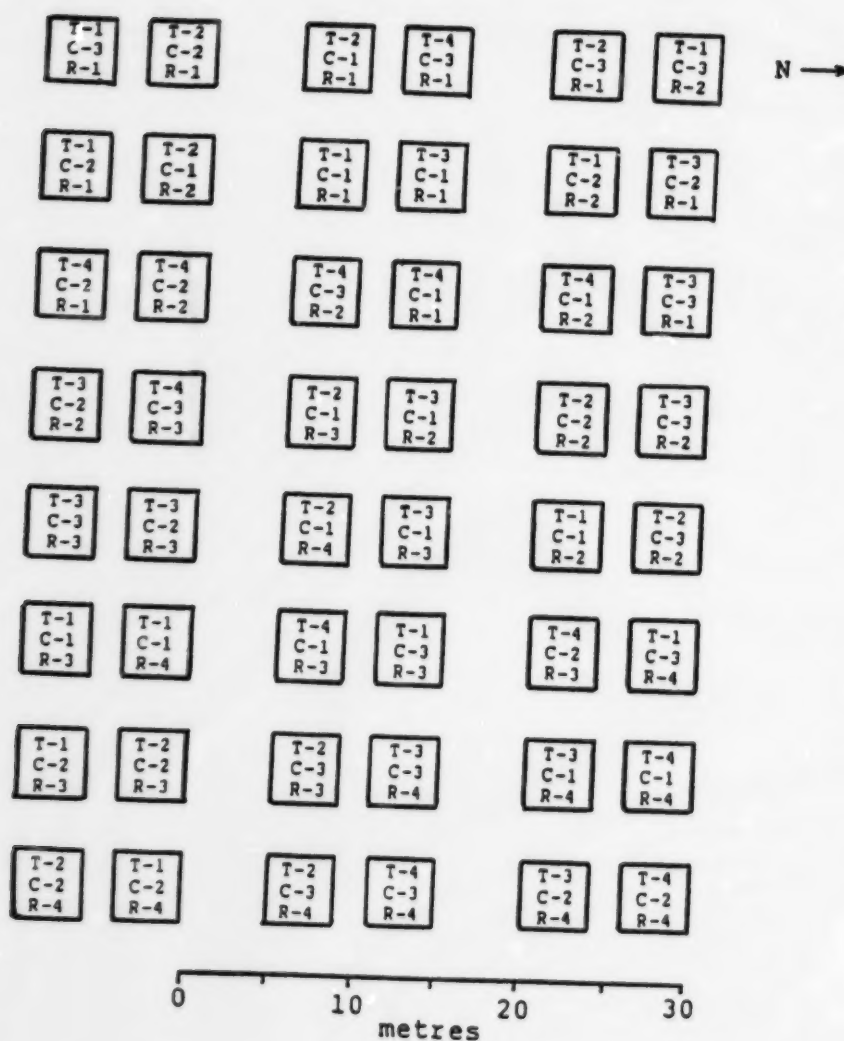
Plots are adjusted to three levels of subsoil compaction to encompass a range consistent with that measured on wellsites in northeastern Alberta. The lowest strength (control) is selected as the lowest compaction level that will not settle and become more compact over the three year duration of the experiment. The most compacted level was chosen to be similar to that on compacted wellsites and found to be limiting to root growth even under field capacity moisture conditions. A 30 cm thick layer of compacted subsoil is used in each plot; 30 cm thick compacted layers have been documented on wellsites in Alberta, and heavy agricultural traffic is capable of compacting soils to more than twice this depth.

For each subsoil compaction level, four depths of topsoil cover are used: 5 cm, 20 cm, 35 cm, and 50 cm. These depths provide a range of conditions: from too little soil to support a crop, even under ideal moisture and nutrient conditions, if subsoil compaction is severe; to sufficient topsoil to support a full crop, regardless of subsoil compaction, under all but the most limiting moisture conditions. The minimum depth is chosen to ensure seedling establishment; the maximum depth is an upper limit of topsoil available for reclamation under any conditions.

Barley has been selected as the test crop based on its widespread cultivation in Alberta, its high salt tolerance (preventing any salt effect from becoming the limiting factor to plant growth) and its use as a monoculture on small plot areas for several years without significant problems. Additional species would undoubtedly provide additional information but would result in a prohibitively large experiment.

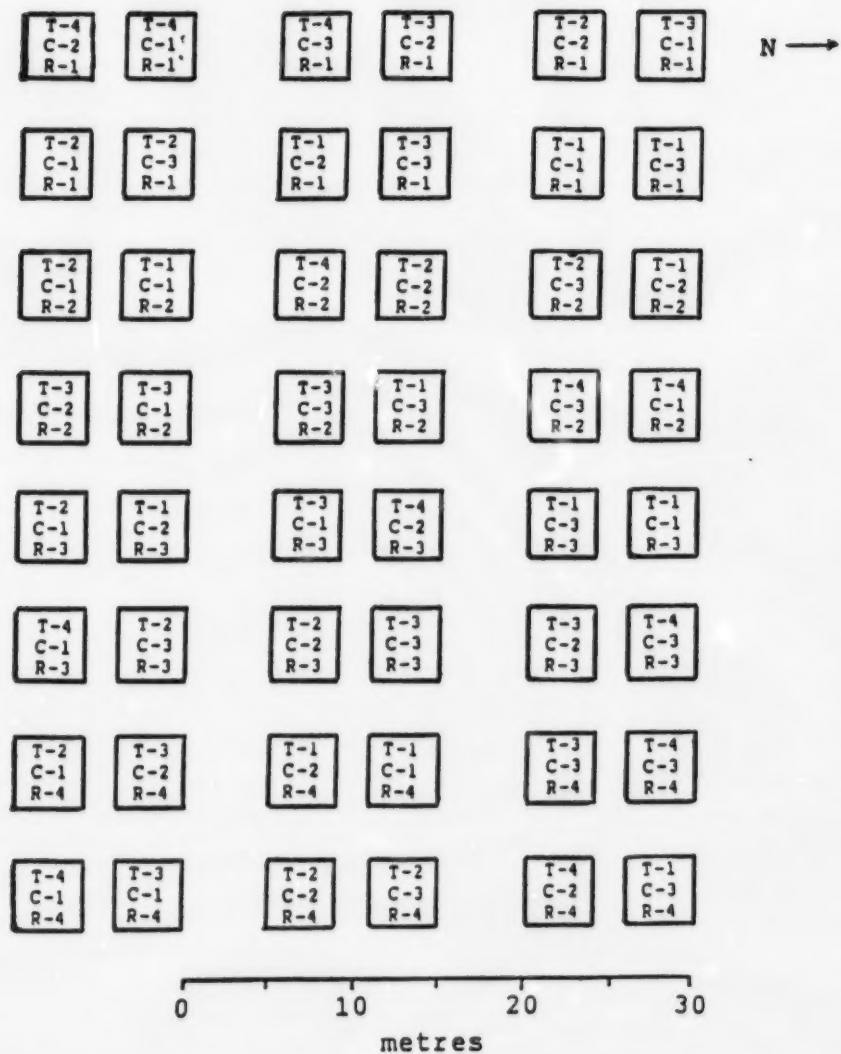
Each plot is 4 m x 4 m such that the total plot area at each site, including walkways and machinery access, encompasses about 0.25 ha with approximately 0.1 ha of cropped area. A 0.5 m margin around each of the plots will be excluded due to border effects, so that the actual sampling area of each plot will be 3 m x 3 m.

Soil strength to the base of the compacted layer will be monitored weekly by using a Centre Cone Penetrometer. This instrument is capable of measuring soil strength up to 110 bars, about four times higher than the point at which root growth ceases, and can be fitted with specially-designed rods to permit strength readings to 80 cm depth. Changes in penetration resistance will reflect changes in soil moisture. Soil cores will be used for monitoring rooting characteristics (once per month) and changes in bulk density and pore size distribution (at the end of the experiment). Grain yield and shoot biomass will be measured at the end of each of three growing seasons. Soil fertility will be measured in the plots and adjusted to a common level each year.



Compaction plot layout at the Chernozemic site, located near Vegreville, Alberta. T indicates topsoil depth, where 1 = 5 cm, 2 = 20 cm, 3 = 35 cm, 4 = 50 cm. C indicates compaction level, where 1 = no compaction, 2 = moderate compaction, 3 = heavy compaction. R indicates replicate number.

Figure 5. Compaction Plot Layout at the Chernozemic Site.



Compaction plot layout at the Luvisolic site, located near Myrnam, Alberta. T indicates topsoil depth, where 1 = 5 cm, 2 = 20 cm, 3 = 35 cm, 4 = 50 cm. C indicates compaction level, where 1 = no compaction, 2 = moderate compaction, 3 = heavy compaction. R indicates replicate number.

Figure 6. Compaction Plot Layout at the Luvisolic Site.

It is anticipated that three years of data will be sufficient to analyze plant response under different growing season conditions. If this time period proves to be insufficient, the study may be extended.

Status: The project is ongoing and is being co-funded by the Alberta Environmental Centre. More information is available from the Centre.

5.6 STERILANTS

Efficiency of Activated Charcoal for Inactivation of Bromacil and Tebuthiuron Residues in Soil - Mr. E. Hemminger

A greenhouse study was conducted at the Alberta Environmental Centre, Vegreville, to investigate the efficiency of activated charcoal for inactivation of bromacil and tebuthiuron residues in soil as influenced by factors such as herbicide:

toxicity of bromacil and tebuthiuron residues. Both herbicides were more phytotoxic when applied to sand or a mixture of sand + soil (1:1, w/w) as compared to a sandy clay loam soil.

Activated charcoal at rates up to 400 ppm in sand, soil or the sand + soil mixture was not phytotoxic when incorporated without the herbicides. Incorporation of activated charcoal at rates ranging from 100 to 400 times the herbicide active ingredients (0.2, 0.8, and 2.0 ppm) protected oats, to varying degrees, from bromacil and tebuthiuron injury. The level of protection varied with the ratio of herbicide to activated charcoal and soil characteristics, mainly the organic matter and clay content. In general, nearly complete protection was achieved when the herbicide to activated charcoal ratio was 1:200 or more.

Protection of oats from bromacil or tebuthiuron injury improved as the time interval



Soil Sterilant. Soil sterilant affected site showing surface runoff causing crop damage.

activated charcoal ratio, soil texture, organic matter content, soil moisture, and the time interval between activated charcoal incorporation and plant establishment. Oat (*Avena sativa* L.) was used as a bioassay species to assess the phyto-

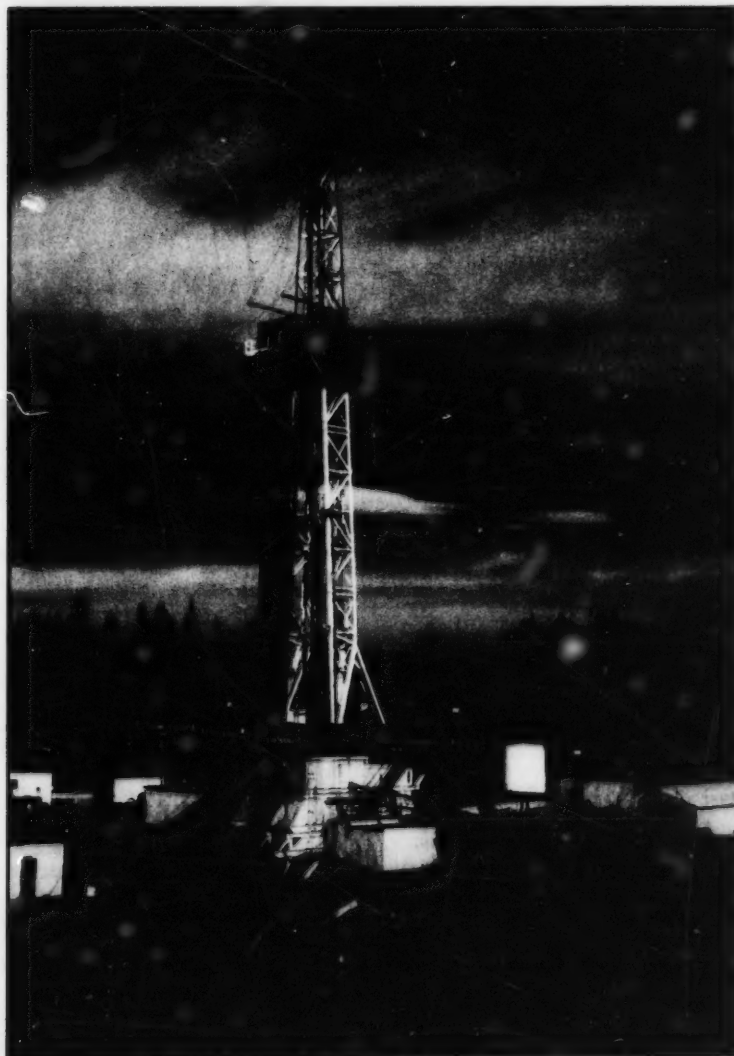
between activated charcoal incorporation and the seeding of oats increased from 0 to 1, 2 or 4, and 6 weeks. A time interval of at least one week was required for optimum binding of bromacil or tebuthiuron residues in soil by

activated charcoal applied at a ratio of 1:100 (herbicide:activated charcoal). A shorter interval was required at a ratio of 1:400.

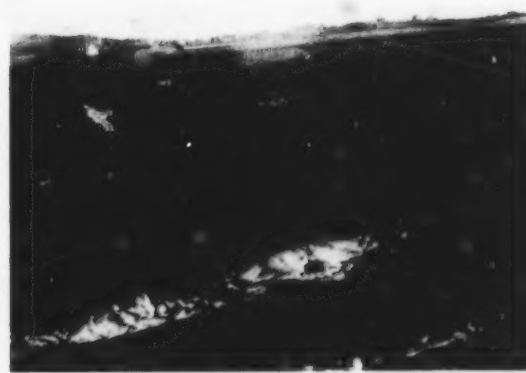
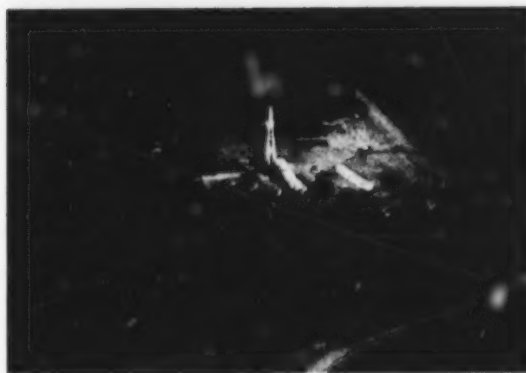
Injury to oat plants from bromacil or tebuthiuron decreased as the soil moisture level decreased. Protection of oat plants from herbicide injury by activated charcoal, especially at lower herbicide: activated charcoal ratios, was slightly better under the lower moisture regimes than at the high moisture regime. This difference was considered due to an increased activity of bromacil and tebuthiuron under optimum moisture conditions rather than a direct effect of low moisture regimes on the efficiency of activated charcoal on herbicide inactivation.

Results of this greenhouse study showed that activated charcoal, at ratios of 1:200 or more (herbicide active ingredient:activated charcoal), can be effectively used to inactivate bromacil and tebuthiuron residues in soil. The efficiency of treatment depends on activated charcoal ratios, soil characteristics (texture, organic matter content and moisture level) and the time interval between activated charcoal incorporation and plant establishment.

Status: Project is finished. The final report has been published: RRTAC 89-3. The study was co-funded by the Alberta Environmental Centre.



Reclamation Research Technical Advisory Committee



Members: Chris Powter (Chairman) - Alberta Environment; Sharon Guenette (Secretary) - Forestry, Lands & Wildlife; Reinhard Hermesh - Alberta Environmental Centre; David Lloyd - Forestry, Lands & Wildlife; Leon Marciak - Alberta Agriculture; Steve Moran - Alberta Research Council; Hari Sahay - Alberta Energy; Sam Takyi - Forestry, Lands & Wildlife; Hugh Wollis - Forestry, Lands & Wildlife.

6. GENERAL PROGRAM

The projects listed under the General Program have application to all the RRTAC Programs and, in some cases, to other disturbance types not studied by RRTAC. These projects are selected and managed by RRTAC rather than by a specific Program Committee.

6.1 PROGRAM DEVELOPMENT

Future Research Needs - J. Smith, Concord Scientific Corporation

RRTAC has provided funding for reclamation research in Alberta for eleven years and is now evaluating future directions for the research program. Concord Scientific Corporation and RRTAC designed a questionnaire to determine the reclamation research needs of organizations/industries in Alberta involved with industrial disturbances. The results of this study will help RRTAC to recommend the direction to be taken in funding research programs over the next five years.

A list of organizations involved with reclamation in Alberta was developed with the assistance of RRTAC. This mailing list included members of industry, consultants, and the provincial and federal governments.

In the detailed questionnaire the following information was requested for each research need identified: the geographic location, type of disturbance, end land-use, and codes to describe the research. Each respondent was asked to list up to ten research areas and to prioritize them from most to least important, with priority ranking 1 representing the most important research need and priority ranking 10 representing the least important of the ten research needs.

The questionnaire was pre-tested with three participants who work in the reclamation field: Al Fedkenheuer of NOVA Corporation of Alberta, Phil Lulman of TransAlta Utilities Corporation, and Dean Mutrie of Tera Environmental Consultants. The participants were asked to review the questionnaire for the following aspects: completeness of the questionnaire in covering relevant topics, clarity and readability of instructions and code options, and format and ease of use

of the questionnaire. The participants were interviewed and the questionnaires were modified based on their recommendations.

A total of 221 questionnaires were mailed. The approximate distribution of the questionnaire by organization/industry affiliation was 51% sent to government, 37% to industry and 12% to consultants. A total of 119 responses were received; 47% from government, 36% from industry, and 17% from consultants. Some respondents provided fewer than 10 research needs, while others provided more. In all, 1214 needs were identified.

From this set, a list of the top 10 needs was prepared based on frequency of response (i.e., the most common needs) and priority (i.e., the most important needs). These top 10 needs will be used in a general sense to help identify program priorities.

However, to identify priorities within programs, the original list of needs was further analyzed by disturbance type and geographic location, and relevant topics placed into the four current RRTAC Program areas. The Oil and Gas Program had the greatest number of needs identified, followed by the Mountains and Foothills Program; the Oil Sand Program and the Plains Coal Program had a similar number of needs identified. The top 10 needs in each program were then identified using a similar frequency/priority analysis.

Status: The project is completed and a summary report is available from the Chairman of RRTAC.

6.2 VEGETATION

Update of Plant Species Suitability Manual - C. Warner, Hardy BBT Limited

In 1980 RRTAC published Report 80-5: Manual of Plant Species Suitability for Reclamation in Alberta, to provide users with information on a variety of plant species suitable for use in reclamation programs in Alberta. The manual was well received by reclamation specialists, plant biologists, ecologists, and the general public, and has recently gone out of print.



Plant Species Manual. Knowing which species are suited to a site makes it easier to reclaim disturbed areas.

Since 1980, new information on the species in the manual has been produced through operational and research activities. In addition, new species and/or varieties have been tested in Alberta. All of this new information needed to be incorporated into an updated manual so that reclamation specialists and other persons interested in vegetation have access to the best information available.

The detailed information (including data and references) from the existing manual and update will be described under the following headings to facilitate information retrieval:

1. Species biology (taxonomy, distribution, propagation, etc.).
2. Tolerances (drought, cold, salt, acid, etc.).
3. Reclamation considerations (seed availability, methods of establishment, current use, etc.).

The existing natural vegetation in the province provides a broad indication of growing conditions and is a useful tool in selecting species for reclamation. The development of the ecoregion map of Alberta by Strong and Leggat adds more information on regional soil and

climate, and will provide an informative and standard base on which to indicate where a species is most suited. The ecoregion map will be modified to suit the purpose and scale of the manual.

The criteria for selection of a species for a particular reclamation site was prioritized. This information is currently in the manual, however it was not readily accessible.

The emphasis in the update of the manual was to add recent Alberta-specific information to the species already listed. However, if new and promising species were identified they were added. Only species with high potential for use in Alberta were selected for addition in the manual.

A major objective in the update of the manual was to add recent (since 1980) Alberta-specific information gained through monitoring of research plots and reclamation sites throughout the province. This information was integrated under the existing headings. Where available, information on years of testing and site location was included, building confidence in the suitability of a particular selection for particular site conditions.

Particular emphasis was placed on gathering information on tolerance to hydrocarbons and trace elements as well as sulphur. The need is increasing for reclamation of industrial sites contaminated with hydrocarbons, (i.e., wellsites), or subject to sulphur dioxide fumigation, (i.e., oil sands region, mines near coal-fired hydro-generation plants, gas plants, etc.). In situations such as those just mentioned, tolerance to these parameters becomes a major selection criteria. New information on these parameters was added and deficiencies were noted.

The major source of update information was annual reclamation monitoring reports submitted to the government for mines, pipelines, gravel operations, and other industrial sites throughout the province. Research plot work at the Alberta Environmental Centre was reviewed as well as applicable RRTAC studies including both field trials and literature reviews. With regard to the latter, RRTAC report 84-1: Land Surface Reclamation: A Review of the International Literature is a valuable source of information. Although most of the literature cited in this report is pre-1980, many of the papers are not referenced in the previous species suitability manual.

In addition, funding from the Recreation, Parks and Wildlife Foundation in 1988 allowed inclusion of line drawings of each species. This has helped make the manual more useful in the field for both specialists and the general public.

Status: The project is completed and a final report has been published: RRTAC 89-4.

6.3 SOILS

Review of Erosion Control Materials and Methods - D. Walker, David Walker & Associates

Control of erosion on reclaimed sites is critical to the success of any reclamation effort. While a vigorous vegetative growth is generally thought to be the optimum erosion control material, there are specific instances where other materials may be required to successfully control erosion.



Erosion Control Study. Sandbags and straw bales used for erosion control on a steep slope.

The objective of this project is to provide a detailed listing of the options available in Alberta, along with documentation of the use and costs of these options.

Status: The project is completed and a final report will be available in 1990.

best storage methods, and to document the length of time topsoil is stored in various Alberta operations.

Status: The project is completed and a final report will be available in 1990.



User Guide for Pit and Quarry. A number of reclamation options are available to the operator of a gravel pit.

Effects of Storage on Topsoil Quality -
B. Valteau, Thurber Consultants Limited

Topsoil replacement assists in reclaiming surface disturbances by providing a good seed bed, nutrients, water holding capacity, and a seed source. Topsoil must be removed and replaced on all regulated surface disturbances in Alberta, and usually on non-regulated disturbances. It is generally accepted that immediate replacement enhances the success of the reclamation effort. However, in some operations, such as mountain mines, producing oil and gas wells and batteries, and industrial facilities, topsoil must be stored for several years before it can be used in reclamation.

The objective of this project is to review the literature to determine the effects of prolonged topsoil storage on topsoil quality, to determine the

A User Guide for Pit and Quarry
Reclamation in Alberta - J. Green, The Delta
Environmental Management Group

Many pits and quarries in Alberta are reclaimed to exactly the same land use as existed previous to mining. However, there are a number of other reclamation options available to the operator or land owner that may greatly improve the use of the land at little extra cost. This project is designed to develop a manual that will outline the options available for a pit given the surrounding land uses, pit size and depth, presence of water, and other factors. Options discussed include agriculture, forestry, fisheries, wildlife habitat, and residential/ industrial development. The manual will be very graphics-oriented and simply written.

Status: The project is completed and a final report should be available in 1990.

7. PREVIOUS RESEARCH

7.1 PLAINS COAL RECLAMATION RESEARCH PROGRAM

Objective: Restoration of Agricultural Capability

PROBLEM AREA	RESEARCH PRIORITIES	DESCRIPTION
Groundwater/ Geology	- Effects of mining on groundwater supplies - Generation of salts in spoil - Transport of salts near the reclaimed soil surface - Subsidence after reclamation - Overburden classification	The regions including and surrounding the Battle River and Highvale Mining areas have been intensively monitored to assess the effects of mining on the soil, water and ultimately, the agricultural resources. The hydrology project is completed. The long-term effects of subsidence, salinization and soil quality are being monitored by ARC. See RRTAC Reports 80-3, 86-2, 86-3, 86-4, 86-5, 86-6, 86-7, 87-9, 87-10, 87-11, 87-12, 87-13, 88-2, 88-4, 88-9, 88-12.
Soil Reconstruction	- Thickness of subsoil required above sodic spoil - Effects of slope on lateral salt transport - Reconstruction of Solonchic soils - Use of bottom ash as a soil amendment - Effects of crop type - Changes in topsoil during stockpiling	Experimental plots were constructed at the Battle River and Highvale Mine areas and monitored for seven and six crop years, respectively. See RRTAC Report 88-11. An experiment to test optimum amounts of bottom ash and incorporation methods has been completed. See RRTAC Report 87-7.
Fly and Bottom Ash Disposal	- Chemical and physical properties of Alberta fly and bottom ashes - Potential for use as soil amendment	Ashes from five Alberta sources were analyzed for both toxicity and soil amendment possibilities. This work is completed. See RRTAC Report 81-3.

7.2 MOUNTAINS AND FOOTHILLS RECLAMATION RESEARCH PROGRAM

Objective: Restoration of Forestry, Wildlife and Watershed Capabilities

PROBLEM AREA	RESEARCH PRIORITIES	DESCRIPTION
Landscape Design	Design and construction of stable spoil dumps	A survey was conducted of existing reclaimed dumps in Alberta and British Columbia to identify practical resloping strategies. A study of erosion of a variety of dump slopes was conducted. See RRTAC Report 87-8.
	Erosion control	Mulches, binders and contouring techniques for erosion control on coal spoil were evaluated.
	Water management	Settling pond size requirements, the scientific basis for water quality objectives, and methods for predicting sediment production were reviewed and evaluated. See RRTAC Reports 86-2, 87-5, 87-6.
Soil Reconstruction	For various land uses	A literature review and evaluation of soil reconstruction requirements was completed. See RRTAC Report 87-2.
	For reclamation of ash dumps	Thickness of soil required over coal ash to support vegetation was investigated.
Revegetation	Species selection	Development, assessment and field testing of native grasses for reclamation is ongoing.
	Propagation	Methods for propagation of reclamation shrubs were assessed.
	Establishment	Methods for establishment of tree seedlings in grass cover were evaluated.
	Fertilization, nutrients	Studies identified treatments important to development of self-sustaining plant cover. See RRTAC Report 80-1.
	Growth	A method for early prediction of tree growth suitability was developed. See RRTAC Report 88-7.
Wildlife Habitat	Techniques Assessment methods	Literature reviews of methods for wildlife habitat reclamation and measurement of reclamation success were completed. See RRTAC Reports 86-9, 88-1.

7.3 OIL SANDS RECLAMATION RESEARCH PROGRAM

Objective: Restoration of Forestry, Wildlife Capabilities and Erosion Control

PROBLEM AREA	RESEARCH PRIORITIES	DESCRIPTION
Soil Reconstruction on Tailings	Identify recipes for reconstructed soils suitable for: - Commercial forest - Non-commercial forest - Erosion control - Wildlife habitat	Identification of the chemical and microbiological properties of peat, and development of mycorrhizal inoculants for jack pine and other woody species. See RRTAC Reports 84-4, 83-3, 88-5. Identification of soil amendment requirements. See RRTAC Report 83-1. This study was fundamental in designing the oil sand soil reconstruction plots which were constructed in 1983.
Revegetation	- Selection - Propagation - Establishment - Management - Sampling	These projects consisted of literature reviews on tree and shrub selection, seed collection, propagation techniques, and sampling methods for use on the soil reconstruction plots. See RRTAC Reports 83-5, 84-2.



7.4 OIL AND GAS RECLAMATION RESEARCH PROGRAM

Objective: To develop safe methods of waste disposal and return land to a condition capable of sustaining a designated land use.

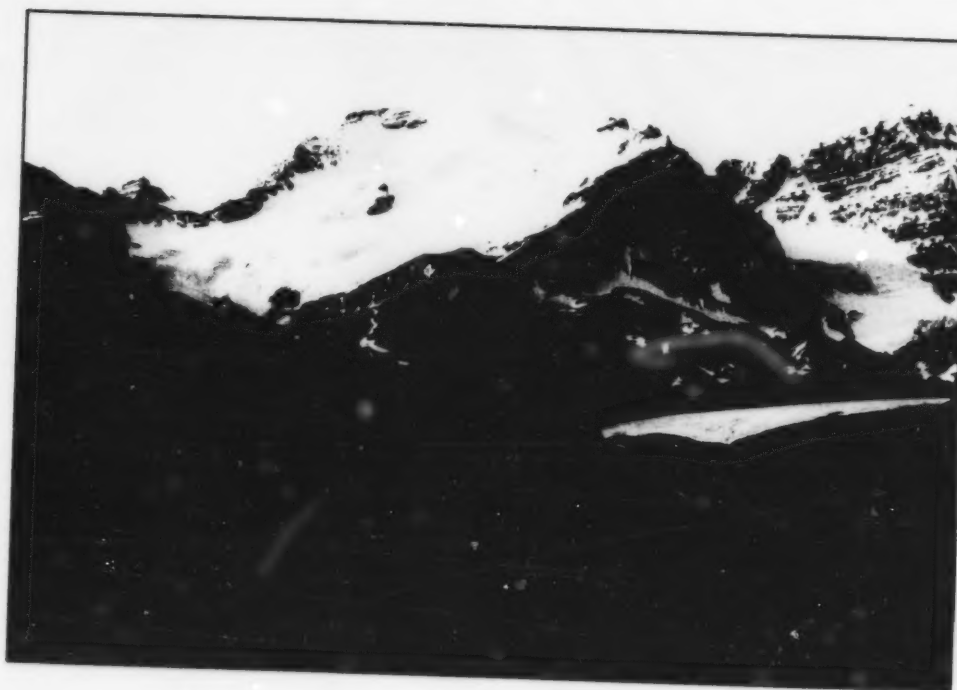
PROBLEM AREA	RESEARCH PRIORITIES	DESCRIPTION
Materials Handling	Identify the best methods for handling soil materials in pipeline construction in agricultural land	A survey was made of pipelines of various ages on all of our major agricultural soil types. Material handling methods were assessed and problem areas identified. See RRTAC Report 83-3.
	Disposal of drilling muds	A literature review of disposal methods for KCl drilling muds was undertaken. See RRTAC Report 87-1.
Drilling Muds	Sumps	A review of clay liners for containment of drilling wastes was completed. See RRTAC Report 88-10. A study was completed assessing the feasibility of developing a computer system for evaluating a proposed sump location.



7.5 GENERAL*

PROBLEM AREA	RESEARCH PRIORITIES	DESCRIPTION
Reclamation Bibliography and Review	Document the findings of reclamation research activities and assess implications for Alberta operations	Worldwide reclamation literature has been reviewed and condensed for presentation in a report which lists and discusses existing information pertinent to reclamation in Alberta. The bibliographic data base is accessible through the University of Alberta computing system. See RRTAC Reports 82-1, 84-1.
Workshops	Conduct workshops to determine research needs in Alberta and to disseminate research findings	See RRTAC Reports 80-4 (Forest Soils), 81-3 (Coal Ash), 83-4 (Eastern Slopes Hydrology), 85-1 (Revegetation in Mountains/Foothills) and 87-3 (Gel and Saline Drilling Wastes).
Reference	Provide sources of information for reclamationists	See RRTAC Reports 80-5 (Plant Species Manual), 81-2 (Survey of Activities), 82-2 (Bibliography of Soils, Geology, Hydrology and Groundwater), and 88-8 (Alberta Forest Service Watershed Management Field and Laboratory Methods).

* Projects with province-wide application.



8. 1989/90 RECLAMATION RESEARCH BUDGET

Project No.	Project	1989/90 Budget (\$)
PLAINS COAL RECLAMATION RESEARCH PROGRAM		
78-20	CAN-AG Enterprises Ltd. Battle River Soil Reconstruction Project	5 285.00
89-01	Alberta Research Council Effects of Perched Ponds on Groundwater and Salinity	15 000.00 ³
89-02	Monenco Consultants Limited Use of Spoil as Subsoil Material	55 483.00
MOUNTAINS AND FOOTHILLS RECLAMATION RESEARCH PROGRAM		
89-08	Ann Smreciu Salinity Screening of Native Grass Species	9 999.00 ²
89-13	Hardy BBT Limited Reclamation of Disturbed Alpine Lands	30 000.00
OIL SANDS RECLAMATION RESEARCH PROGRAM		
83-07	Hardy BBT Limited Oil Sands Soil Reconstruction Project	55 842.00 ^{1,5}
89-11	Hardy BBT Limited An Analysis of Vegetation Data from Reclaimed Areas	14 999.00
OIL & GAS RECLAMATION RESEARCH PROGRAM		
86-32B	Milner Engineering Ltd. Soil Compaction	24 793.00 ²
89-03	Alberta Research Council Update of the Drilling Waste Disposal Manual	22 909.00
89-04	Alberta Research Council Landfarming of Diesel Invert Drilling Wastes	75 000.00 ³
89-06	Monenco Consultants Limited Literature Review on the Environmental Acceptability of Drilling Waste Burial	24 669.00
89-12	Alberta Research Council CPA Sump Chemistry Study	16 379.00
GENERAL PROGRAM		
88-2	Hardy BBT Limited Update of Plant Species Suitability Manual	10 667.00
89-05	David Walker & Associates Review of Erosion Control Materials and Methods	24 921.00 ⁴
89-07	Thurber Consultants Limited Effects of Storage on Topsoil Quality	25 000.00
89-14	Delta Environmental Management Group A User's Guide to Pit and Quarry Reclamation Publications	39 000.00 30 216.00
TOTAL RRTAC		\$ 480 162.00

Co-funding Agencies

- ¹ Syncrude Canada Ltd.
- ² Alberta Environmental Centre
- ³ Alberta Research Council
- ⁴ Alberta Transportation
- ⁵ Suncor Inc.

RRTAC funds are provided by the Alberta Heritage Savings Trust Fund.

9. RECLAMATION RESEARCH REPORTS

RRTAC 79-2: Proceedings: Workshop on Native Shrubs in Reclamation. P.F. Ziemkiewicz, C.A. Dermott and H.P. Sims (Editors). 104 pp. No longer available.

The Workshop was organized as the first step in developing a Native Shrub reclamation research program. The Workshop provided a forum for the exchange of information and experiences on three topics: propagation; outplanting; and, species selection. Seven papers and the results of three discussion groups are presented.

RRTAC 80-1: Test Plot Establishment: Native Grasses for Reclamation. R.S. Sadasivalah and J. Weljer. 19 pp. No longer available.

The report details the species used at three test plots in Alberta's Eastern Slopes (one at Caw Creek Ridge and two at Cadomin). Site preparation, experimental design, and planting method are also described.

RRTAC 80-3: The Role of Organic Compounds in Salinization of Plains Coal Mining Sites. N.S.C. Cameron et al. 46 pp. \$10.00

This is a literature review of the chemistry of sodic mine spoil and the changes expected to occur in groundwater.

RRTAC 80-4: Proceedings: Workshop on Reconstruction of Forest Soils in Reclamation. P.F. Ziemkiewicz, S.K. Takyl and H.F. Regier (Editors). 160 pp. \$10.00.

Experts in the field of forestry and forest soils report on research relevant to forest soil reconstruction and discuss the most effective means of restoring forestry capability of mined lands.

RRTAC 80-5: Manual of Plant Species Suitability for Reclamation in Alberta. L.E. Watson, R.W. Parker and D.F. Polster. 2 vols, 541 pp. No longer available.

Forty-three grass, fourteen forb, and thirty-four shrub and tree species are assessed in terms of their suitability for use in reclamation. Range maps, growth habit, propagation, tolerance, and availability information are provided.

RRTAC 81-2: 1980 Survey of Reclamation Activities in Alberta. D.G. Walker and R.L. Rothwell. 76 pp. \$10.00

This survey is an update of a report prepared in 1976 on reclamation activities in Alberta, and includes research and operational reclamation, locations, personnel, etc.

RRTAC 81-3: Proceedings: Workshop on Coal Ash and Reclamation. P.F. Ziemkiewicz, R. Stein, R. Leitch and G. Lutwick (Editors). 253 pp. \$10.00

Presents nine technical papers on the chemical, physical, and engineering properties of Alberta fly and bottom ashes, revegetation of ash disposal sites, and use of ash as a soil amendment. Workshop discussions and summaries are also included.

RRTAC 82-1: Land Surface Reclamation: An International Bibliography. H.P. Sims and C.B. Powter. 2 vols, 292 pp. \$10.00

Literature to 1980 pertinent to reclamation in Alberta is listed in Vol. 1 and is also on the University of Alberta computing system (in a SPIRES database called RECLAIM). Vol. 2 comprises the keyword index and computer access manual.

RRTAC 82-2: A Bibliography of Baseline Studies in Alberta: Soils, Geology, Hydrology and Groundwater. C.B. Powter and H.P. Sims. 97 pp. \$5.00

This bibliography provides baseline information for persons involved in reclamation research or in the preparation of environmental impact assessments. Materials, up to date as of December 1981, are available in the Alberta Environment Library.

RRTAC 83-1: Soil Reconstruction Design for Reclamation of Oil Sand Tailings. Monenco Consultants Ltd. 185 pp. No longer available

Volumes of peat and clay required to amend oil sand tailings were estimated based on existing literature. Separate soil prescriptions were made for spruce, jack pine, and herbaceous cover types. The estimates form the basis of field trials.

RRTAC 83-3: Evaluation of Pipeline Reclamation Practices on Agricultural Lands in Alberta. Hardy Associates (1978) Ltd. 205 pp. No longer available.

Available information on pipeline reclamation practices was reviewed. A field survey was then conducted to determine the effects of pipe size, age, soil type, construction method, etc. on resulting crop production.

RRTAC 83-4: Proceedings: Effects of Coal Mining on Eastern Slopes Hydrology. P.F. Ziemkiewicz (Editor). 123 pp. \$10.00

Technical papers are presented dealing with the impacts of mining on mountain watersheds, their flow characteristics, and resulting water quality. Mitigative measures and priorities were also discussed.

RRTAC 83-5: Woody Plant Establishment and Management for Oil Sands Mine Reclamation. Techman Engineering Ltd. 124 pp. No longer available.

This is a review and analysis of information on planting stock quality, rearing techniques, site preparation, planting, and procedures necessary to ensure survival of trees and shrubs in oil sand reclamation.

RRTAC 84-1: Land Surface Reclamation: A Review of the International Literature. H.P. Sims, C.B. Powter and J.A. Campbell. 2 vols, 1549 pp. No longer available.

Nearly all topics of interest to reclamationists including mining methods, soil amendments, revegetation, propagation and toxic materials are reviewed in light of the international literature.

RRTAC 84-2: Propagation Study: Use of Trees and Shrubs for Oil Sand Reclamation. Techman Engineering Ltd. 58 pp. \$10.00

This report evaluates and summarizes all available published and unpublished information on large-scale propagation methods for shrubs and trees to be used in oil sand reclamation.

RRTAC 84-3: Reclamation Research Annual Report - 1983. P.F. Ziemkiewicz. 42 pp. \$5.00

This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results, and expenditures.

RRTAC 84-4: Soil Microbiology in Land Reclamation. D. Parkinson, R.M. Danielson, C. Griffiths, S. Visser and J.C. Zak. 2 vols, 676 pp. \$10.00

This is a collection of five reports dealing with re-establishment of fungal decomposers and mycorrhizal symbionts in various amended spoil types.

RRTAC 85-1: Proceedings: Revegetation Methods for Alberta's Mountains and Foothills. P.F. Ziemkiewicz (Editor). 416 pp. \$10.00

Results of long-term experiments and field experience on species selection, fertilization, reforestation, topsoiling, shrub propagation and establishment are presented.

RRTAC 85-2: Reclamation Research Annual Report - 1984. P.F. Ziemkiewicz. 29 pp. \$5.00

This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results, and expenditures.

RRTAC 86-1: A Critical Analysis of Settling Pond Design and Alternative Technologies. A. Somani. 372 pp. \$10.00

The report examines the critical issue of settling pond design, and sizing and alternative technologies. The study was co-funded with The Coal Association of Canada.

RRTAC 86-2: Characterization and Variability of Soil Reconstructed after Surface Mining in Central Alberta. T.M. Macyk. 146 pp. No longer available.

Reconstructed soils representing different materials handling and replacement techniques were characterized, and variability in chemical and physical properties was assessed. The data obtained indicate that reconstructed soil properties are determined largely by parent material characteristics and further tempered by materials handling procedures. Mining tends to create a relatively homogeneous soil landscape in contrast to the mixture of diverse soils found before mining.

RRTAC 86-3: Generalized Procedures for Assessing Post-Mining Groundwater Supply Potential in the Plains of Alberta - Plains Hydrology and Reclamation Project. M.R. Trudell and S.R. Moran. 30 pp. \$5.00

In the Plains region of Alberta, the surface mining of coal generally occurs in rural, agricultural areas in which domestic water supply requirements are met almost entirely by groundwater. Consequently, an important aspect of the capability of reclaimed lands to satisfy the needs of a residential component is the post-mining availability of groundwater. This report proposes a sequence of steps or procedures to identify and characterize potential post-mining aquifers.

RRTAC 86-4: Geology of the Battle River Site: Plains Hydrology and Reclamation Project. A. Maslowski-Schutze, R. Li, M. Fenton and S.R. Moran. 86 pp. \$10.00

This report summarizes the geological setting of the Battle River study site. It is designed to provide a general understanding of geological conditions adequate to establish a framework for hydrogeological and general reclamation studies. The report is not intended to be a detailed synthesis such as would be required for mine planning purposes.

RRTAC 86-5: Chemical and Mineralogical Properties of Overburden: Plains Hydrology and Reclamation Project. A. Maslowski-Schutze. 71 pp. \$10.00

This report describes the physical and mineralogical properties of overburden materials in an effort to identify individual beds within the bedrock overburden that might be significantly different in terms of reclamation potential.

RRTAC 86-6: Post-Mining Groundwater Supply at the Battle River Site: Plains Hydrology and Reclamation Project. M.R. Trudell, G.J. Sterenberg and S.R. Moran. 49 pp. \$5.00

The report deals with the availability of water supply in or beneath cast overburden to support post-mining land use, including both quantity and quality considerations. The study area is in the Battle River Mining area in east-central Alberta.

RRTAC 86-7: Post-Mining Groundwater Supply at the Highvale Site: Plains Hydrology and Reclamation Project. M.R. Trudell. 25 pp. \$5.00

This report evaluates the availability of water supply in or beneath cast overburden to support post-mining land use, including both quantity and quality considerations. The study area is the Highvale mining area in west-central Alberta.

RRTAC 86-8: Reclamation Research Annual Report - 1985. P.F. Ziemkiewicz. 54 pp. \$5.00

This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results, and expenditures.

RRTAC 86-9: Wildlife Habitat Requirements and Reclamation Techniques for the Mountains and Foothills of Alberta. J.E. Green, R.E. Salter and D.G. Walker. 285 pp. No longer available.

This report presents a review of relevant North American literature on wildlife habitats in mountain and foothills biomes, reclamation techniques, potential problems in wildlife habitat reclamation, and potential habitat assessment methodologies. Four biomes (Alpine, Subalpine, Montane, and Boreal Uplands) and 10 key wildlife species (snowshoe hare, beaver, muskrat, elk, moose, caribou, mountain goat, bighorn sheep, spruce grouse, and white-tailed ptarmigan) are discussed. The study was co-funded with The Coal Association of Canada.

RRTAC 87-1: Disposal of Drilling Wastes. L.A. Leskiw, E. Reini-Dwyer, T.L. Dabrowski, B.J. Rutherford and H. Hamilton. 210 pp. No longer available.

Current drilling waste disposal practices are reviewed and criteria in Alberta guidelines are assessed. The report also identifies research needs and indicates mitigation measures. A manual provides a decision-making flowchart to assist in selecting methods of environmentally safe waste disposal.

RRTAC 87-2: Minesoil and Landscape Reclamation of the Coal Mines in Alberta's Mountains and Foothills. A.W. Fedkenheuer, L.J. Knapik and D.G. Walker. 174 pp. \$10.00

This report reviews current reclamation practices with regard to site and soil reconstruction and reestablishment of biological productivity. It also identifies research needs in the Mountain-Foothills area. The study was co-funded with The Coal Association of Canada.

RRTAC 87-3: Gel and Saline Drilling Wastes in Alberta: Workshop Proceedings. D.A. Lloyd (Compiler). 218 pp. No longer available.

Technical papers were presented which describe: mud systems used and their purpose; industrial constraints; government regulations, procedures and concerns; environmental considerations in waste disposal; and toxic constituents of drilling wastes. Answers to a questionnaire distributed to participants are included in an appendix.

RRTAC 87-4: Reclamation Research Annual Report - 1986. 50 pp. \$5.00

This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results, and expenditures.

RRTAC 87-5: Review of the Scientific Basis of Water Quality Criteria for the East Slope Foothills of Alberta. Beak Associates Consulting Ltd. 46 pp. \$10.00

The report reviews existing Alberta guidelines to assess the quality of water drained from coal mine sites in the East Slope Foothills of Alberta. World literature was reviewed within the context of the East Slopes environment and current mining operations. The ability of coal mine operators to meet the various guidelines is discussed. The study was co-funded with The Coal Association of Canada.

RRTAC 87-6: Assessing Design Flows and Sediment Discharge on the Eastern Slopes. Hydrocon Engineering (Continental) Ltd. and Monenco Consultants Ltd. 97 pp. \$10.00

The report provides an evaluation of current methodologies used to determine sediment yields due to rainfall events in well-defined areas. Models are available in Alberta to evaluate water and sediment discharge in a post-mining situation. SEDIMOT II (Sedimentology Disturbed Modelling Techniques) is a single storm model that was developed specifically for the design of sediment control structures in watersheds disturbed by surface mining and is well suited to Alberta conditions. The study was co-funded with The Coal Association of Canada.

RRTAC 87-7: The Use of Bottom Ash as an Amendment to Sodic Spoil. S. Fullerton. 83 pp. No longer available.

The report details the use of bottom ash as an amendment to sodic coal mine spoil. Several rates and methods of application of bottom ash to sodic spoil were tested to determine which was the best at reducing the effects of excess sodium and promoting crop growth. Field trials were set up near the Vesta mine in East Central Alberta using ash readily available from a nearby coal-fired thermal generating station. The research indicated that bottom ash incorporated to a depth of 30 cm using a subsoiler provided the best results.

RRTAC 87-8: Waste Dump Design for Erosion Control. R.G. Chopluk and S.E. Thornton. 45 pp. \$5.00

This report describes a study to evaluate the potential influence of erosion from reclaimed waste dumps on downslope environments such as streams and rivers. Sites were selected from coal mines in Alberta's mountains and foothills, and included resloped dumps of different configurations and ages, and having different vegetation covers. The study concluded that the average annual amount of surface erosion is minimal. As expected, erosion was greatest on slopes which were newly regraded. Slopes with dense grass cover showed no signs of erosion. Generally, the amount of erosion decreased with time, as a result of initial loss of fine particles, the formation of a weathered surface, and increased vegetative cover.

RRTAC 87-9: Hydrogeology and Groundwater Chemistry of the Battle River Mining Area. M.R. Trudell, R.L. Faught and S.R. Moran. 97 pp. No longer available.

This report describes the premining geologic conditions in the Battle River coal mining area including the geology as well as the groundwater flow patterns, and the groundwater quality of a sequence of several water-bearing formations extending from the surface to a depth of about 100 metres.

RRTAC 87-10: Soil Survey of the Plains Hydrology and Reclamation Project - Battle River Project Area. T.M. Macyk and A.H. MacLean. 62 pp. plus 8 maps. \$10.00

The report evaluates the capability of post-mining landscapes and assesses the changes in capability as a result of mining, in the Battle River mining area. Detailed soils information is provided in the report for lands adjacent to areas already mined as well as for lands that are destined to be mined. Characterization of the reconstructed soils in the reclaimed areas is also provided. Data were collected from 1979 to 1985. Eight maps supplement the report.

RRTAC 87-11: Geology of the Highvale Study Site: Plains Hydrology and Reclamation Project. A. Maslowski-Schutze. 78 pp. \$10.00

The report is one of a series that describes the geology, soils and groundwater conditions at the Highvale Coal Mine study site. The purpose of the study was to establish a summary of site geology to a level of detail necessary to provide a framework for studies of hydrogeology and reclamation.

RRTAC 87-12: Premining Groundwater Conditions at the Highvale Site. M.R. Trudell and R. Faught. 83 pp. \$10.00

This report presents a detailed discussion of the premining flow patterns, hydraulic properties, and isotopic and hydrochemical characteristics of five layers within the Paskapoo Geological Formation, the underlying sandstone beds of the Upper Horseshoe Canyon Formation, and the surficial glacial drift.

RRTAC 87-13: An Agricultural Capability Rating System for Reconstructed Soils. T.M. Macyk. 27 pp. \$5.00

This report provides the rationale and a system for assessing the agricultural capability of reconstructed soils. Data on the properties of the soils used in this report are provided in RRTAC 86-2.

RRTAC 88-1: A Proposed Evaluation System for Wildlife Habitat Reclamation in the Mountains and Foothills Biomes of Alberta: Proposed Methodology and Assessment Handbook. T.R. Eccles, R.E. Salter and J.E. Green. 101 pp. plus appendix. \$10.00

The report focuses on the development of guidelines and procedures for the assessment of reclaimed wildlife habitat in the Mountains and Foothills regions of Alberta. The technical section provides background documentation including a discussion of reclamation planning, a listing of reclamation habitats and associated key wildlife species, conditions required for development, recommended revegetation species, suitable reclamation techniques, a description of the recommended assessment techniques and a glossary of basic terminology. The assessment handbook section contains basic information necessary for evaluating wildlife habitat reclamation, including assessment scoresheets for 15 different reclamation habitats, standard methodologies for measuring habitat variables used as assessment criteria, and minimum requirements for certification. This handbook is intended as a field manual that could potentially be used by site operators and reclamation officers. The study was co-funded with The Coal Association of Canada.

RRTAC 88-2: Plains Hydrology and Reclamation Project: Spoil Groundwater Chemistry and Its Impacts on Surface Water. M.R. Trudell (Compiler). 135 pp. \$10.00

Two reports comprise this volume. The first "Chemistry of Groundwater in Mine Spoil, Central Alberta," describes the chemical make-up of spoil groundwater at four mines in the Plains of Alberta. It explains the nature and magnitude of changes in groundwater chemistry following mining and reclamation. The second report, "Impacts of Surface Mining on Chemical Quality of Streams in the Battle River Mining Area," describes the chemical quality of water in streams in the Battle River mining area, and the potential impact of groundwater discharge from surface mines on these streams.

RRTAC 88-3: Revegetation of Oil Sands Tailings: Growth Improvement of Silver-berry and Buffalo-berry by Inoculation with Mycorrhizal Fungi and N₂-Fixing Bacteria. S. Visser and R.M. Danielson. 98 pp. \$10.00

The report provides results of a study: (1) To determine the mycorrhizal affinities of various actinorrhizal shrubs in the Fort McMurray, Alberta region; (2) To establish a basis for justifying symbiont inoculation of buffalo-berry and silver-berry; (3) To develop a growing regime for the greenhouse production of mycorrhizal, nodulated silver-berry and buffalo-berry; and, (4) To conduct a field trial on reconstructed soil on the Syncrude Canada Limited oil sands site to critically evaluate the growth performance of inoculated silver-berry and buffalo-berry as compared with their uninoculated counterparts.

RRTAC 88-4: Plains Hydrology and Reclamation Project: Investigation of the Settlement Behaviour of Mine Backfill. D.R. Pauls (compiler). 135 pp. \$10.00

This three part volume covers the laboratory assessment of the potential for subsidence in reclaimed landscapes. The first report in this volume, "Simulation of Mine Spoil Subsidence by Consolidation Tests," covers laboratory simulations of the subsidence process particularly as it is influenced by resaturation of mine spoil. The second report, "Water Sensitivity of Smectitic Overburden: Plains Region of Alberta," describes a series of laboratory tests to determine the behaviour of overburden materials when brought into contact with water. The report entitled "Classification System for Transitional Materials: Plains Region of Alberta," describes a lithological classification system developed to address the characteristics of the smectite rich, clayey transition materials that make up the overburden in the Plains of Alberta.

RRTAC 88-5: Ectomycorrhizae of Jack Pine and Green Alder: Assessment of the Need for Inoculation, Development of Inoculation Techniques and Outplanting Trials on Oil Sand Tailings. R.M. Danielson and S. Visser. 177 pp. \$10.00

The overall objective of this research was to characterize the mycorrhizal status of Jack Pine and Green Alder which are prime candidates as reclamation species for oil sand tailings and to determine the potential benefits of mycorrhizae on plant performance. This entailed determining the symbiont status of container-grown nursery stock and the quantity and quality of inoculum in reconstructed soils, developing inoculation techniques and finally, performance testing in an actual reclamation setting.

RRTAC 88-6: Reclamation Research Annual Report - 1987. Reclamation Research Technical Advisory Committee. 67 pp. No longer available.

This annual report describes the expenditure of \$500,000.00 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

RRTAC 88-7: Baseline Growth Performance Levels and Assessment Procedure for Commercial Tree Species in Alberta's Mountains and Foothills. W.R. Dempster and Associates Ltd. 66 pp. \$5.00

Data on juvenile height development of lodgepole pine and white spruce from cut-over or burned sites in the Eastern Slopes of Alberta were used to define reasonable expectations of early growth performance as a basis for evaluating the success of reforestation following coal mining. Equations were developed predicting total seedling height and current annual height increment as a function of age and elevation. Procedures are described for applying the equations, with further adjustments for drainage class and aspect, to develop local growth performance against these expectations. The study was co-funded with The Coal Association of Canada.

RRTAC 88-8: Alberta Forest Service Watershed Management Field and Laboratory Methods. A.M.K. Nip and R.A. Hursey. 4 Sections, various pagings. \$10.00

Disturbances such as coal mines in the Eastern Slopes of Alberta have the potential for affecting watershed quality during and following mining. The collection of hydrometric, water quality and hydro-meteorologic information is a complex task. A variety of instruments and measurement methods are required to produce a record of hydrologic inputs and outputs for a watershed basin. There is a growing awareness and recognition that standardization of data acquisition methods is required to ensure data comparability, and to allow comparison of data analyses. The purpose of this manual is to assist those involved in the field of data acquisition by outlining methods, practices and instruments which are reliable and recognized by the International Organization for Standardization.

RRTAC 88-9: Computer Analysis of the Factors Influencing Groundwater Flow and Mass Transport in a System Disturbed by Strip Mining. F.W. Schwartz and A.S. Crowe. 78 pp. \$10.00

Work presented in this report demonstrates how a groundwater flow model can be used to study a variety of mining-related problems such as declining water levels in areas around the mine as a result of dewatering, and the development of high water tables in spoil once resaturation is complete. This report investigates the role of various hydrogeological parameters that influence the magnitude, timing, and extent of water level changes during and following mining at the regional scale. The modelling approach described here represents a major advance on existing work.

RRTAC 88-10: Review of Literature Related to Clay Liners for Sump Disposal of Drilling Wastes. D.R. Pauls, S.R. Moran and T. Macyk. 61 pp. \$5.00

The report reviews and analyses the effectiveness of geological containment of drilling waste in sumps. Of particular importance was the determination of changes in properties of clay materials as a result of contact with highly saline brines containing various organic chemicals.

RRTAC 88-11: Highvale Soil Reconstruction Project: Five Year Summary. D.N. Graveland, T.A. Oddie, A.E. Osborne and L.A. Panek. 104 pp. \$10.00

This report provides details of a five year study to determine a suitable thickness of subsoil to replace over minespoil in the Highvale plains coal mine area to ensure return of agricultural capability. The study also examined the effect of slope and aspect on agricultural capability. This study was funded and managed with industry assistance.

RRTAC 88-12: A Review of the International Literature on Mine Spoil Subsidence. J.D. Scott, G. Zinter, D.R. Pauls and M.B. Dusseault. 36 pp. \$10.00

The report reviews available engineering literature relative to subsidence of reclaimed mine spoil. The report covers methods for site investigation, field monitoring programs and lab programs, mechanisms of settlement, and remedial measures.

RRTAC 89-1: Reclamation Research Annual Report - 1988. 74 pp. \$5.00

This annual report describes the expenditure of \$280,000.00 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

RRTAC 89-2: Proceedings of the Conference: Reclamation, A Global Perspective. D.G. Walker, C.B. Powter and M.W. Pole (Compilers). 2 Vols., 854 pp. \$10.00

Over 250 delegates from all over the world attended this conference held in Calgary in August, 1989. The proceedings contains over 85 peer-reviewed papers under the following headings: A Global Perspective; Northern and High Altitude Reclamation; Fish & Wildlife and Rangeland Reclamation; Water; Herbaceous Revegetation; Woody Plant Revegetation and Succession; Industrial and Urban Sites; Problems and Solutions; Sodic and Saline Materials; Soils and Overburden; Acid Generating Materials; and, Mine Tailings.

RRTAC 89-3: Efficiency of Activated Charcoal for Inactivation of Bromacil and Tebuthiuron Residues in Soil. M.P. Sharma. 38 pp. \$5.00

Bromacil and Tebuthiuron were commonly used soil sterilants on well sites, battery sites and other industrial sites in Alberta where total vegetation control was desired. Activated charcoal was found to be effective in binding the sterilants in greenhouse trials. The influence of factors such as herbicide:charcoal concentration ratio, soil texture, organic matter content, soil moisture, and the time interval between charcoal incorporation and plant establishment were evaluated in the greenhouse.

RRTAC 89-4: Manual of Plant Species Suitability for Reclamation in Alberta - 2nd Edition. Hardy BBT Limited. 436 pp. \$10.00

This is an updated version of RRTAC Report 80-5 which describes the characteristics of 43 grass, 14 forb and 34 shrub and tree species which make them suitable for reclamation in Alberta. The report has been updated in several important ways: a line drawing of each species has been added; the range maps for each species have been redrawn based on an ecosystem classification of the province; new information (to 1990) has been added, particularly in the sections on reclamation use; and the material has been reorganized to facilitate information retrieval. Of greatest interest is the performance chart that precedes each species and the combined performance charts for the grass, forb, and shrub/tree groups. These allow the reader to pick out at a glance species that may suit their particular needs. The report was produced with the assistance of a grant from the Recreation, Parks and Wildlife Foundation.

RRTAC 89-5: Battle River Soil Reconstruction Project Five Year Summary. L.A. Leskiw. 188 pp. \$10.00

This report summarizes the results of a five year study to investigate methods required to return capability to land surface mined for coal in the Battle River area of central Alberta. Studies were conducted on: the amounts of subsoil required, the potential of gypsum and bottom ash to amend adverse soil properties, and the effects of slope angle and aspect. Forage and cereal crop growth was evaluated, as were changes in soil chemistry, density and moisture holding characteristics.

RRTAC 89-6: Detailed Sampling, Characterization and Greenhouse Pot Trials Relative to Drilling Wastes in Alberta. T.M. Macyk, F.I. Nikiforuk, S.A. Abboud and Z.W. Widtman. 228 pp. \$10.00

This report summarizes a three-year study of the chemistry of freshwater gel, KCl, NaCl, DAP, and invert drilling wastes, both solids and liquids, from three regions in Alberta: Cold Lake, Eastern Slopes, and Peace River/Grande Prairie. A greenhouse study also examined the effects of adding various amounts of waste to soil on grass growth and soil chemistry. Methods for sampling drilling wastes are recommended.

RRTAC 89-7: A User's Guide for the Prediction of Post-Mining Groundwater Chemistry from Overburden Characteristics. M.R. Trudell and D.C. Cheel. 55 pp. \$5.00

This report provides the detailed procedure and methodology that is required to produce a prediction of post-mining groundwater chemistry for plains coal mines, based on the soluble salt characteristics of overburden materials. The fundamental component of the prediction procedure is the geochemical model PHREEQE, developed by the U.S. Geological Survey, which is in the public domain and has been adapted for use on personal computers.